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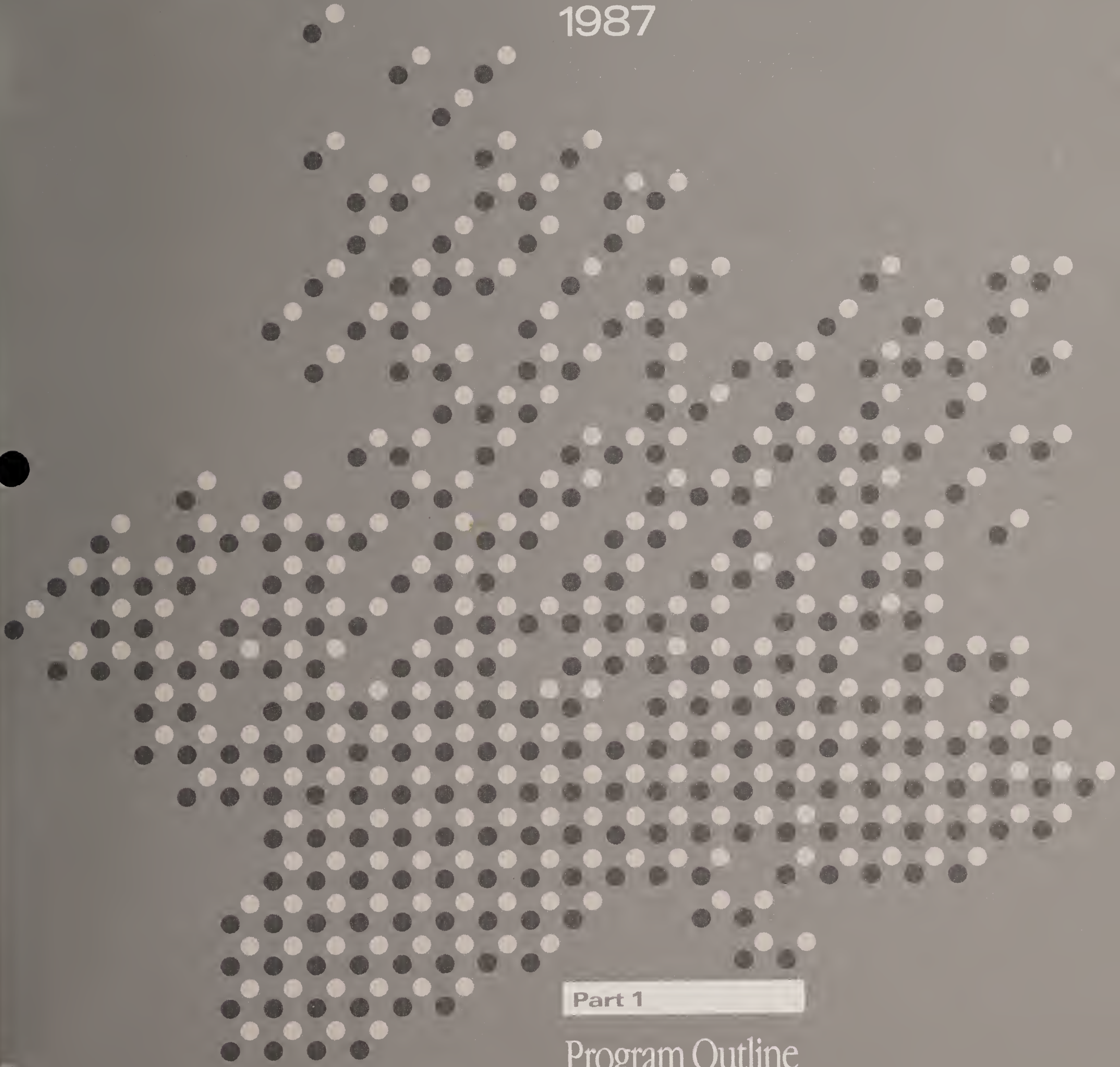
Curriculum Guideline

Science

Intermediate and Senior Divisions

1987



Part 1

Program Outline and Policy

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Preface

This guideline consists of fifteen parts, each in a separate booklet as indicated on page 3. The entire set of booklets is called *the guideline*. It outlines the expectations of the Ministry of Education for the development and implementation of science courses in the Intermediate and Senior Divisions in the province of Ontario.

This particular document is Part 1 of the guideline and sets the stage for the science program; it establishes the framework within which each of the science courses described in Parts 2 to 15 is to be taught. The course descriptions include specific subject matter, while Part 1 prescribes other, complementary components that are essential to the courses. *In designing and implementing science courses at the local level, teachers must blend the components of Part 1 with the subject matter indicated in the course descriptions outlined in Parts 2 to 15.*

In the interpretation of policy, the following information is important:

- Many statements in the guideline are, by their very nature, prescriptive. These are indicated by the words *shall*, *will*, *must*, and *is/are to be*.
- A number of statements are recommendatory. These are usually identified by the word *should*. While such statements are to be considered as strong advice, in some circumstances alternative policies or actions may be justified locally.
- Other statements indicate optionality. They are identified by such words as *may*, *might*, *can*, and *could*.

Introduction

The Parts of the Guideline

This guideline brings to the province of Ontario a renewal of the curriculum in science programs for Grades 7 to 12 and the Ontario Academic Courses (OACs). The entire guideline consists of the following parts:

Part 1: Program Outline and Policy
Part 2: Science, Grades 7 and 8
Part 3: Science, Grades 9 and 10, General Level
Part 4: Science, Grades 9 and 10, Advanced Level
Part 5: Science, Grades 9 and 10, Basic Level
Part 6: Science, Grades 11 and 12, Basic Level
Part 7: Environmental Science, Grades 10 to 12, General Level
Part 8: Environmental Science, Grades 10 and 12, Advanced Level
Part 9: Applied Biology and Applied Chemistry, Grade 11, General Level
Part 10: Applied Physics and Technological Science, Grade 12, General Level
Part 11: Geology, Grade 12, General and Advanced Levels
Part 12: Biology, Grade 11, Advanced Level, and the OAC
Part 13: Chemistry, Grade 11, Advanced Level, and the OAC
Part 14: Physics, Grade 12, Advanced Level, and the OAC
Part 15: Science in Society, OAC

Guideline Courses

Table 1 on page 4 indicates the courses that may be included in a science program in the Intermediate and Senior Divisions. Appendix A contains a list of the formal names of the courses with their course codes.

A school need not offer all of the courses described in this guideline. However, in the context of such factors as its student enrolment, staff size, and overall program, a school should ensure that the range of science courses that is available accommodates the needs, interests, and abilities of all of its students. Courses should be available to students at more than one level of difficulty.

The science courses offered in Grades 7 to 12 and the science OACs shall conform to the course descriptions prescribed in this curriculum guideline.

Superseded Guidelines

This curriculum guideline replaces the following guidelines:

- *Agriculture RP.21, 1962*
- *Biology RP.50, 1963*
- *Biology, Grade 13, 1969*
- *Chemistry RP.51, 1965*
- *Chemistry S.17D, 1966*
- *Chemistry S.17E, 1967*
- *Environmental Science, Intermediate and Senior Divisions, 1973*
- *Geology RP.47, 1963*
- *Physics S.17A(11), 1966*
- *Physics S.17C, 1967*
- *Science, Intermediate Division, 1978*
- *Science RP.17, 1964*
- the Science (Technical) courses and the Industrial Chemistry courses for Grades 11 and 12 outlined in *Technical Subjects RP.27, Intermediate and Senior Divisions, 1963*

Note: The following curriculum guidelines will no longer be in effect as of September 1, 1989:

- *Man, Science and Technology, Intermediate and Senior Divisions, 1972* (for Grades 9 to 12)
- *Space and Man, Senior Division, 1969* (for Grades 11 and 12)

Table 1: Authorized Science Guideline Courses, Intermediate and Senior Divisions

	Basic Level	General Level	Advanced Level
Grade 7		Science	
Grade 8		Science	
Grade 9	Science (SNC1B)	Science (SNC1G)	Science (SNC1A)
Grade 10	Science (SNC2B)	Science (SNC2G) Environmental Science (SEN2G)	Science (SNC2A) Environmental Science (SEN2A)
Grade 11	Science (SNC3B)	Applied Biology (SBA3G) Applied Chemistry (SCA3G) Environmental Science (SEN3G)	Biology (SBI3A) Chemistry (SCH3A)
Grade 12	Science (SNC4B)	Environmental Science (SEN4G) Geology (SGE4G) Applied Physics (SPA4G) Technological Science (STE4G)	Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)
OACs			Biology (SBI0A) *Prerequisite* – Biology (SBI3A) Chemistry (SCH0A) *Prerequisite* – Chemistry (SCH3A) Physics (SPH0A) *Prerequisite* – Physics (SPH4A) Science in Society (SSO0A) *Prerequisite – One of:* Biology (SBI3A) Chemistry (SCH3A) Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)

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*Since the Grade 12 advanced-level geology course described in the guideline (see Part II) may be taught under the aegis of a geography department as Geology (GGE4A)–note the course-code change – then either Geology (SGE4A) or Geology (GGE4A) may count as a prerequisite to Science in Society (SSO0A).

A. Goals and Aims

Sections

1. The Value and Purpose of Science Education
2. The Goals of Education and the Role of Science
3. The Aims of the Science Curriculum

Section 1

The Value and Purpose of Science Education

Science is a quest for knowledge about nature – a search to understand the cause-and-effect relationships that govern the structure and behaviour of natural phenomena. It involves questions, discoveries, interpretations, applications, implications, and more questions.

Science education allows students to feel the excitement of gaining scientific expertise and the satisfaction of knowing how to use scientific knowledge. Specifically, science education offers the following characteristics and benefits:

- an empirical quality, which requires students to pursue solutions to both qualitative and quantitative problems through investigation and verification;
- an analytical quality, which challenges them to discover plausible explanations, underlying patterns, conceptual frameworks, and theoretical suppositions;
- a linguistic individuality, a unique way of thinking and talking about the world, which requires them to convey objective ideas with accuracy, precision, and substantive argument based on reliable evidence;
- a dimensional quality, which provides a context for numerical problem solving, through the addition of the concept of physical quantity to numerical problems;
- a physiological aspect, which provides them with an understanding of human biology and the interrelationships between humans and the environment that affects and sustains them;
- a technological aspect, which allows them to appreciate the impact of technological innovations on society and to share intelligently in decision making about their use;
- a sociological aspect. Many of the current and future needs of students and society relate directly or indirectly to science. Education in science will help students meet such needs as:

  a) coping well in the areas of life management and raising children;
  b) maintaining healthy bodies;
  c) earning a living;
  d) evaluating and respecting views different from their own;
  e) anticipating far-reaching changes in human behaviour;
  f) surviving on this planet;
  g) utilizing natural resources wisely and efficiently;
  h) making ethical decisions about such issues as genetic engineering, robotization, population control, world hunger, chemical and biological warfare, and nuclear disarmament;
  i) solving interrelated environmental, political, social, economic, scientific, and technological problems;
  j) handing on to the next generation the best and most practical perspectives on science education;
  k) maintaining a positive outlook on life and recognizing the benefits that science can bring to enhance life on earth.

In addition to its value to the individual student, science education has far-reaching implications, which include the following:

- Much of human knowledge, which is the major resource of the post-industrial era, along with its processing and retrieval, is rooted in science.
- Science affords the opportunity to break down national barriers and bring people across the world together in enterprises that are co-operative, productive, and mutually beneficial.
- Science can provide the means for rich countries to help poorer countries. The sharing of scientific knowledge and technology can help build a better future for all peoples.

The characteristics of science and the needs of society indicate that science education should be given high priority in the schooling of all young people. In one way or another practically every vocation, practical or professional, is affected by science. For example, a student who aspires to become a lawyer may in the future be required to deal with the legal implications of such issues as the use of carcinogens, teratogens, and radioactive isotopes; acid and toxic rain; and the global greenhouse effect of carbon loading of the atmosphere. The thalidomide and Minamata disasters are evidence of the need for practitioners of law to be conversant with the principles of science.

It is important that students develop a knowledge of the world, a sense of their place in it, and the belief that they can influence events in it. Human concern can be exerted to control and improve the future well-being of individuals and society. Students can apply the knowledge they derive from science education to enhance their health and environment, their use of energy and land, the ways they spend time and money, their contributions to the political system, and the attitudes they have towards themselves, one another, and society as a whole.

From an overall perspective, science education is intended to support and contribute to the goals of education. Such goals have been enunciated for the province of Ontario and are stated in the next section.

Section 2

The Goals of Education and the Role of Science

School boards are responsible for ensuring that science programs reflect the goals of education in Ontario and help "individual learners to achieve their potential in physical, intellectual, emotional, social, cultural, and moral development."[1] ***The goals of education consist of helping each student to:***

1. ***develop a responsiveness to the dynamic processes of learning***

   Processes of learning include observing, sensing, inquiring, creating, analysing, synthesizing, evaluating, and communicating. The dynamic aspect of these processes derives from their source in many instinctive human activities, their application to real-life experiences, and their systematic interrelation within the curriculum.

   In science courses both substantive content and scientific processes are essential. Opportunities for student activities are provided in all courses described in the guideline; in fact, many such activities are mandatory. The experimental nature of science is to be emphasized, since it is this characteristic that makes it a dynamic process of learning.

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[1] Ontario, Ministry of Education, *Ontario Schools, Intermediate and Senior Divisions (Grades 7-12/OACs): Program and Diploma Requirements* (Toronto: Ministry of Education, Ontario, 1984), subsection 1.3. This publication will be referred to as OSIS in subsequent citations.

2. ***develop resourcefulness, adaptability, and creativity in learning and living***

   These attributes apply to modes of study and inquiry, to the management of personal affairs such as career plans and leisure activities, and to the ability to deal effectively with challenge and change.

   Science courses are to provide students with a variety of modes of study and inquiry: reading, obtaining data, experimenting, designing testing techniques, changing variables, questioning, evaluating, seeking solutions to problems, theorizing, and explaining. Science should also be related to career awareness, possible leisure pursuits, and preparation for coping with life.

3. ***acquire the basic knowledge and skills needed to comprehend and express ideas through words, numbers, and other symbols***

   Such knowledge and skills will assist the learner in applying rational and intuitive processes to the identification and solution of problems by:

   a) using language aptly as a means of communication and an instrument of thought;
   b) reading, listening, and viewing with comprehension and insight;
   c) understanding and using mathematical operations and concepts.

   Science abounds in ideas, facts, concepts, theories, laws, terminology, quantities, and symbols. Such content should be mastered by students to help them identify and solve problems and to investigate experimentally. Communicating, reading, listening, observing, thinking, searching sources, evaluating data, and understanding and using mathematics are important components. Language use and development are to be integral parts of all science courses.

4. ***develop physical fitness and good health***

   Factors that contribute to fitness and good health include regular physical activity, an understanding of human biology and nutrition, the avoidance of health hazards, and concern for personal well-being.

   The study of science should expand students' vision of the need for fitness, good health, and accident prevention. Safety must be given special emphasis. The discussion of factors that lead to personal well-being and confidence in life management should be given high priority.

5. ***gain satisfaction from participating and from sharing the participation of others in various forms of artistic expression***

   Artistic expression involves the clarification and restructuring of personal perception and experience. It is found in the visual arts, music, drama, and literature, as well as in other areas of the curriculum where both the expressive and receptive capabilities of the learner are being developed.

   In science students should be given the opportunity to observe and sense the beauty and intricacy of nature. The fragrances of flowers, the colours of the spectrum, the structures of crystals, and the motions of the planets can add to students' enjoyment of their environment. Science provides opportunities to study form, shape, and movement. Human reaction to the world of science is often evident in songs, plays, poems, artistic expression, and literature. Particular use should be made of the wealth of artistic and photographic material depicting animals, plants, and other items and phenomena of scientific interest. Paintings of Canadian wildlife provide excellent examples. The arts and sciences should be complementary studies.

6. ***develop a feeling of self-worth***

   A feeling of self-worth is affected by internal and external influences. Internally it is fostered by realistic self-appraisal, confidence, and conviction in the pursuit of excellence, self-discipline, and the satisfaction of achievement. Externally it is reinforced by encouragement, respect, and supportive evaluation.

   Science activities and projects of appropriate challenge can be used to foster confidence, excellence, and satisfaction. Therefore, students should be encouraged to perform exemplary work with their hands as well as their minds in the pursuit of excellence. The evaluation of student achievement – affective, psychomotor, and cognitive – should enhance educational growth and foster further learning.

7. ***develop an understanding of the role of the individual within the family and the role of the family within society***

   Within the family the individual shares responsibility, develops supportive relationships, and acquires values. Within society the family contributes to the stability and quality of a democratic way of life.

   A consideration of the societal implications of scientific phenomena can enable students of science to appreciate the influence that individuals and sectors of society can exert on one another. Students will come to understand the role of the individual in a group if they are treated in a democratic way and if they are allowed to share responsibility and to contribute to the common good.

8. ***acquire skills that contribute to self-reliance in solving practical problems in everyday life***

   These skills relate to the skilful management of personal resources, effective participation in legal and civic transactions, the art of parenthood, responsible consumerism, the appropriate use of community agencies and services, the application of accident-prevention techniques, and a practical understanding of the basic technology of home maintenance.

   Science courses should provide opportunities for students to manage time, look at the legal and societal implications of scientific issues, study cost applications, apply safety measures, and understand technological applications. The everyday life needs of students, both present and future, should serve as a guide to the selection of examples to illustrate scientific and technological concepts.

9. ***develop a sense of personal responsibility in society at the local, national, and international levels***

   Awareness of personal responsibility in society grows out of knowledge and understanding of one's community, one's country, and the rest of the world. It is based on an understanding of social order, a respect for the law and the rights of others, and a concern for the quality of life at home and abroad.

   Students should realize the responsibility of individuals, communities, industry, and governments towards society in matters related to scientific issues, such as resources, pollution, hygiene, nutrition, animal and plant care, and safety. Courses should promote an interest in scientific applications, especially local ones, to industry, meteorology, agriculture, medicine, forestry, engineering, and other areas. Achievements of scientists in the local community, Ontario, Canada, and other nations should be identified.

10. ***develop esteem for the customs, cultures, and beliefs of a wide variety of societal groups***

    This goal is related to social concord and individual enrichment. In Canada it includes regard for:

    a) the Native peoples;
    b) the English and French founding peoples;
    c) multiculturalism;
    d) national identity and unity.

    An emphasis should be placed on science as an international enterprise and the need to use its benefits for the good of all humanity, particularly for the deprived nations of the world. Discussions of the beliefs of various groups about topics such as origins, health, diets, the weather, conservation, and the universe might be appropriate and useful. This goal can be partially achieved by emphasizing co-operation among students in the activities conducted in the laboratory.

11. ***acquire skills and attitudes that will lead to satisfaction and productivity in the world of work***

    In addition to the appropriate academic, technical, and interpersonal skills, this goal relates to good work habits, flexibility, initiative, leadership, the ability to cope with stress, and regard for the dignity of work.

    Excellence in courses offered at the various levels of difficulty should be required in science. Creativity and leadership can be fostered in laboratory activities. Courses should reflect the need for academic, technological, and interpersonal skills within the scientific enterprise. Students' studies should frequently be related to the integrity of the subject, technological productivity, and employment opportunities.

12. ***develop respect for the environment and a commitment to the wise use of resources***

    This goal relates to a knowledgeable concern for the quality of the environment, the careful use of natural resources, and the humane treatment of living things.

    Science courses should emphasize this goal. Students should not only be knowledgeable about what constitutes a positive environmental ethic, but should also incorporate this into their behaviour. They should be given opportunities to improve the environment, use resources wisely, and care for living things.

13. ***develop values related to personal, ethical, or religious beliefs and to the common welfare of society***

    Moral development in the school depends in part on a consideration of ethical principles and religious beliefs, a respect for the ideals held by others, and the identification of personal and societal values.

    Many ethical and moral issues relate to science. Discussions on such matters should help students to consider, at least tentatively, their own convictions, beliefs, and values regarding scientific issues. This ongoing process should be accompanied by objective, open-ended discussion, characterized by sincere respect for the ideals held by students and their parents.

The preceding goals are not arranged in any hierarchical order, nor are they discrete categories from which a checklist should be made. The integrated nature of learning and the complex pattern of human development preclude such a sequential or fragmented approach. The translation of the goals into curriculum objectives, however, will undoubtedly result in sequences of learning appropriate to the particular levels and stages of development of the students for whom programs are being planned.

Section 3

The Aims of the Science Curriculum

3.1 The Aims

The goals of education may be realized in part through learning experiences based on the aims of the science curriculum. Such aims are focused on developing in students an ability to manage their own lives, an acceptable attitude towards the world of work, an understanding of the nature of science, and some degree of scientific literacy.

Students will acquire the following attitudes, skills, and knowledge, which constitute the aims of the science curriculum:

1. ***an understanding of the processes of science***
   These processes include identifying a problem, hypothesizing, observing, classifying, measuring, communicating, inferring, formulating theories and models, gathering data, experimenting, analysing, concluding, explaining, and generalizing. Inherent in science are basic assumptions such as cause and effect, predictability, objectivity, and other characteristics attributed to the nature of science (see subsection 3.2). Students must realize that science is limited by its methods and assumptions and that its theories are subject to change. Nevertheless, science provides an organized explanation of natural phenomena.

2. ***skills that are essential for participation in scientific work and technology***
   The "scientific method", based on empirical findings and logical reasoning, plays a vital role not only in science but also in technology and science education. Those engaged in science activities must possess facility with language, computational ability, inquiry skills, manual dexterity, receptive

attitudes, and social sensitivity. If students are to develop such qualities, their science courses must provide opportunities for them to communicate and calculate, to engage in investigative activities, to interact with nature and the technological world, and to grapple with societal issues.

3. ***facility in problem solving through science***
   Students must be given opportunities to use scientific information, concepts, and processes to formulate arguments; to solve problems, both qualitative and quantitative; and to reach conclusions. They should also develop the ability to apply personal and societal values to the process of decision making, particularly at the interface between science and society.

4. ***the basic knowledge needed to function in and contribute to a scientific and technological world***
   Through science education, students should assimilate basic factual information and understand concepts and conceptual networks related to scientific processes and skills. That is, they are expected to achieve a degree of scientific literacy (see subsection 3.3), which will allow them to:

   - display curiosity about and enjoyment of scientific phenomena in the world around them;
   - appreciate science as it applies to personal life management;
   - enter employment with a suitable background in the fundamentals of science;
   - pursue further studies in science;
   - explore local and global science-related issues;
   - adapt to technological changes;
   - interpret scientific features in newspapers, magazines, journals, and books, and on television.

5. ***respect for the environment and a commitment to the wise use of resources***
   The science program should enable students to develop an environmental ethic that incorporates:

   - an empathy with nature and its complex interactions;
   - a respect for living things;
   - a consideration of the effects of actions on the environment;
   - an understanding of the needs and desires of human beings and how these influence environmental decisions.

6. ***an understanding of the nature of science as a human endeavour***
   Science depends on people working together and sharing information, not only on the knowledge that is produced but also on the processes of inquiry. This dual aspect of the nature of science must be made apparent to students. Further, they are to be given opportunities to understand the relationships between science and society in such areas as economics, consumerism, history, politics, law, sports, and the arts.

7. ***an appreciation of technology as the application of scientific knowledge and principles***
   Students are to realize that many of the benefits of science are derived through technology. Students should become familiar with local, national, and international examples of the interaction between science and technology. Such examples should highlight career opportunities.

8. ***an ability to locate and retrieve scientific information***
   It is important that students learn to utilize various sources of scientific information such as textbooks, handbooks, journals, periodicals, reference materials, video and audio resources, the media, and computers. While students need to assimilate much knowledge, it is also essential that they learn how to learn on their own and how to find and organize scientific information when required. Because of the increasing role of computers in science, students should learn how to operate them and understand their potential in scientific work.

9. ***an awareness of the career possibilities in the field of science and technology***
   A large number of careers now require familiarity with the knowledge and processes of science, and this number will increase as many traditional jobs are replaced by high-technology employment. Female as well as male students should be encouraged to enjoy science and consider the possibilities of careers in science and technology.

10. ***an awareness of how the knowledge of science enhances personal life management***
    Useful applications of science abound in the lives of students. An understanding of nutrition and health, medicine and safety, plants and animals, the environment and natural resources, chemical reactions and energy transfer, properties of matter and radiation, atoms and space, measures and dimensions, and appliances and machines will help students enrich and manage their own lives at school and in the years beyond.

11. ***a sensitivity about science and its influence on societal issues and values***
    Students need to be informed about and to begin to develop considerate and constructive values related to issues that will be raised throughout the science program. Such issues include population growth, origins and futures, respect for life, sexuality, food and famine, drug abuse, biological/chemical/nuclear destruction, hazardous wastes, depletion of resources, environmental control, space exploration, and scientific research.

Note: Because the achievement of the aims of the science curriculum requires the use of a broad range of materials beyond the normal science textbook, the science teacher is advised to work with the teacher-librarian in planning, preparing, and presenting resource-based units. The science teacher should be thoroughly familiar with subsection 2.11 of OSIS and with *Partners in Action: The Library Resource Centre in the School Curriculum* (Toronto: Ministry of Education, Ontario, 1982).

Activities and materials in the school's resource centre should directly support science program objectives that are derived from the above aims. The teacher-librarian can share with the science teacher in curriculum planning; in the development and teaching of library, research, and learning skills; and in the evaluation, selection, and use of learning materials. In addition, the teacher-librarian's knowledge about information networks, the use of computerized data bases, courseware and lessonware, other technological aids to student learning, and new methods of organizing resources can be of immense assistance to the science teacher.

3.2 The Nature of Science

Scientific knowledge changes constantly; however, the nature of science, although multifaceted, is consistent. Throughout this guideline, **scientific knowledge is regarded as being:**

1. ***tentative***
   Scientific knowledge is open-ended, not final or absolute. Past knowledge and conjecture have provided a basis for today's science; today's understandings, updated and refined, will provide the basis for tomorrow's beliefs and understandings. Thus, science is contained in a historical context and is subject to continual revision.

2. ***replicable and universal***
   Knowledge gained in science is based on evidence that, at least in principle, can be repeatedly demonstrated in various places at different times and is independent of individual investigators. An essential variation in evidence requires a revision of the previously assumed knowledge. Different investigators may make a variety of tentative hypotheses to seek to explain the same phenomenon. Eventually consistent conclusions are sought.

3. ***empirical***
   Scientific knowledge develops from experimentation. Quantitative measurements and sense perceptions leading to empirical data are the foundation blocks on which science is constructed. Theories are useful, but the investigative process for generating new knowledge is the characteristic that gives science its unique nature. The processes of inquiry provide the products that are called *knowledge*.

4. ***human***
   Science is a process experienced by human beings. It is an activity motivated by people seeking to find patterns in, and explanations of, natural phenomena. Quantitative measurements are verifiable and generally characterized by objectivity. However, qualitative observations and related theories or models are influenced by the personal characteristics of the observer, who is influenced to some degree by subjectivity. "Great science can neither be predicted nor programmed. Like great art, great science is an intensely human activity that brings to the forefront the scientist's subjectivity – that faculty which shapes creatively both the form and the substance of a new conceptual structure. To be unaware of the subjective nature of great science is to be ignorant of the dynamics of science."[2]

5. ***limited***
   The domain of science is limited to the natural world or universe – basically to the study of matter and energy. Science is distinct from certain realms of knowledge, such as religion. Perspectives from any position – science, religion, or any other viewpoint – should be recognized and respected for their own intrinsic values and contributions to human knowledge. Society must resolve issues by reaching value decisions based on scientific, economic, political, societal, and moral factors.

6. ***probabilistic***
   Science often permits uncertainty principles and probable deductions, particularly when explanations, predictions, and extrapolations are applied to natural phenomena. Even quantitative measurements can have a degree of inaccuracy and often lead to conclusions that are restricted to certain situations.

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[2] John S. Rigden, "The Art of Great Science", *Phi Delta Kappan* 64:9 (May 1983), p. 614.

7. ***imaginative***
   Much of science deals with hypotheses, theories, models, and idealized situations: a cord without mass is said to operate a frictionless pulley, electrons have been compared to orbiting planets, and DNA is modelled with colourful plastics and interlocking coded parts. The theories and models enable scientists to visualize explanations, which in turn lead to further investigations that influence revisions of the theory or model under consideration.

8. ***conceptual***
   Science is governed by key concepts or conceptual networks, which are expressed qualitatively or mathematically. Among these key concepts, which may be developed to varying degrees of complexity in the science classroom, according to student ability, are the following:

   a) cause and effect (Nature is not capricious.)
   b) constancy of behaviour (Many reproducible results provide certainty.)
   c) the perpetuity of nature (The physical universe is assumed to be operating in the same way as it did "millions" of years ago, for example, with regard to the rate of radioactive decay.)
   d) change (Everything appears to be in the process of becoming different or something else; continental shifts are an example.)
   e) orderliness (Patterns and laws exist in nature; the periodic table of elements is an example.)
   f) entropy (Randomness or disorder increases in a closed system, for example, the first law of thermodynamics.)
   g) conservation (Certain entities are conserved in spite of change, for example, energy/mass and momentum.)
   h) periodicity (Predictable cycles exist, for example, the seasons.)
   i) equilibrium (Tendencies to change often occur in opposite directions as a system seeks to achieve a balance, for example, osmosis.)
   j) organism (A dynamic system is characterized by the processes of life and its continuance. The reproduction of cells is an example.)
   k) quantification (Measurement provides a numerical dimension to a concrete or abstract attribute, for example, mass and time.)
   l) field (A region of influence often exists without direct contact, for example, gravity.)
   m) validation (A multiplicity of verifications permits an accurate conclusion until a modification is required, for example, $F = ma$.)

9. ***integrative***
   Science deals with a great variety of disciplines, such as biology, chemistry, physics, environmental science, geology, astronomy, and earth science. It relates to mathematics, technology, geography, physical and health education, family studies, computer studies, engineering, medicine, forestry, agriculture, mining, and a host of other fields. In spite of the diversity of science, all of its branches and applications contribute to overall conceptual schemes that are internally consistent.

10. ***imperative***
    The nature of science is such that it demands reaction. Science calls for decision making. Students learn how smoking harms the body and then they must decide to continue to indulge, to refrain, or perhaps to campaign against the habit. The nature of science is inextricably woven into the behaviour and decision-making patterns of human beings and requires both an individual and a collective response.

3.3 Scientific Literacy

Among the aims of the science curriculum is the achievement of scientific literacy. This process, begun in students' formative years, is to be further developed in their Intermediate and Senior years. It is of prime importance to have students in science classes seeking to develop, to some extent, the attributes of the scientifically literate person. Indeed, the success of a science program might be assessed on the basis of the degree to which scientific literacy is achieved.

The scientifically literate person is one who:

a) understands scientific concepts, principles, and conceptual networks;
b) puts scientific knowledge to practical use;
c) realizes that science is a human endeavour involving both process and product;
d) knows that all phenomena cannot be understood immediately and that sometimes theories are used to provide tentative explanations;
e) recognizes not only the usefulness of science but its limitations as well; knows that scientific knowledge is subject to change; and distinguishes between scientific fact and personal opinion;
f) uses reliable scientific and technological information in the process of personal life management and societal decision making;
g) communicates both his/her scientific knowledge and the process of inquiry;
h) applies science concepts, theories, processes, and values in investigating everyday problems and in making responsible decisions;

i) respects the ethics of the scientific method;
j) appreciates the importance of the scientific enterprise and responds to the stimulus and enrichment afforded by the scientific community;
k) interrelates science and technology, realizing that both of them influence and are influenced by society;
l) relates science to other fields of learning, such as the social sciences, humanities, health sciences, business and technological studies, and the arts;
m) has a rich and exciting view of the universe, the world, and the environment as a result of a knowledge of science, its applications, and its implications;
n) develops an interest in science-related skills – cognitive, manipulative, and attitudinal – that may be applied to lifelong learning, to career awareness, and to leisure pursuits;
o) interacts with various components of his/her universe in a manner that is consistent with a sound environmental ethic;
p) values scientific and technological research and development.

3.4 Curriculum Emphases – Blending Curriculum Aims With Content

In teaching the science curriculum, the teacher is faced with the problem of combining content with the development of the aims of the science curriculum (see subsection 3.1). In this guideline the term *curriculum emphases* refers to the combinations of content and curriculum aims. Too often, content assumes pre-eminence, or the treatment of the emphases is limited to brief comments by the teacher or, if time permits, a short class discussion. In a unit on electricity, for example, a teacher may choose to blend students' "respect for the environment and a commitment to the wise use of resources" (aim 5) with content about electrical energy. However, such an emphasis is often confined to a token reminder to students to turn off the lights when they leave a room. (The name given to this particular emphasis in table 2 is the "environmental-ethic emphasis".)

It is useful, therefore, in dealing with curriculum emphases to see the teaching of science as accomplishing two things at the same time. For example, in teaching the Grade 7 core unit 1, "The Nature of Science", a teacher instructing students about either the motion of a maple samara or the effect of an airplane's propeller is teaching specific content from the discipline of physics. But he/she should also consider the reason for teaching the particular content and incorporate that emphasis into the lesson. For example, the teacher might decide that he/she wishes to develop students' awareness that technology makes use of scientific knowledge (aim 7). In that case, content knowledge about motion might be taught in the context of technological design, with students' being asked to work out the design of either a cardboard samara or a model propeller that is to perform in various ways. Because students have to both do the technological design and interpret what is happening on the basis of scientific concepts, they come to appreciate the relationship between science and technology. In this way a curriculum emphasis, the "science-technology emphasis", has been attempted.

This guideline specifies that several different curriculum emphases are required in the Ontario science program for the Intermediate and Senior Divisions (see subsection 5.7). The aims of the science curriculum, stated in subsection 3.1, when blended with content, may be implemented as the curriculum emphases[3] listed in table 2.

Table 2: Curriculum Emphases

Aim	Plus	Content	Equals	Curriculum Emphasis
Aim 1	+	Content	=	Nature-of-science emphasis
Aim 2	+	Content	=	Skill-development emphasis
Aim 3	+	Content	=	Science-and-society emphasis
Aim 4	+	Content	=	Knowledge-foundation emphasis
Aim 5	+	Content	=	Environmental-ethic emphasis
Aim 6	+	Content	=	Human-endeavour emphasis
Aim 7	+	Content	=	Science-technology emphasis
Aim 8	+	Content	=	Information-processing emphasis
Aim 9	+	Content	=	Science-in-employment emphasis
Aim 10	+	Content	=	Life-management emphasis
Aim 11	+	Content	=	Societal-values emphasis

Thus there are several different contexts in which the science content of this guideline can be taught. The following is an example of how science content can be presented in the context of a selected curriculum emphasis for core unit 4, "Heat", in the Grade 10 advanced-level science course. Two curriculum emphases have been chosen: the nature-of-science emphasis and the environmental-ethic emphasis.

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[3] For another description of seven common curriculum emphases in science teaching, see D.A. Roberts, "Developing the Concept of 'Curriculum Emphases' in Science Education", *Science Education* 66:2 (April 1982), pp. 243-60.

Initially, in the development of the design for teaching a unit or several units of study, an overall "story line" that links the content to the curriculum aim might be adopted. For a nature-of-science emphasis, for example, this story line might be the way in which scientific theories change. Students then attempt to explain the phenomena of heat, first on the basis of the caloric theory, in which heat is conceptualized as a fluid, and, subsequently, in terms of the kinetic-molecular theory, in which heat is conceptualized as a result of particle motion. By learning the particular content topics to be taught in this context, students get the impact of both the content objectives and a set of objectives about the nature of science.

A feasible story line about concepts of heat in the context of an environmental-ethic emphasis is the design of a home heating system. Content topics such as kinetic-molecular theory, quantity of heat, heat of combustion, conduction and insulation, and the nature and effects of convection currents and radiation can be sequenced in the context of a simulation that involves students in solving problems related to heating a home efficiently.

Similarly, the core unit "Green Plants" in Grade 9 general-level science can be approached through a science-and-society emphasis involving a story line based on agriculture; through a nature-of-science emphasis that focuses on the historical development of the concept of photosynthesis; through a skill-development emphasis in a context that stresses the centrality of instrumentation (e.g., microscopy) in the development of knowledge about green plants; or through a life-management emphasis that underlines the benefits of the agrifood business, consumer foods, nutritious diets, and good health.

These are only examples. Sources of ideas for blending content with context can be found in the professional literature, in textbooks, in available curriculum materials, in discussions with colleagues, and in books that extend basic science into such areas as engineering, biotechnology, politics, medicine, urban planning, and economics, to name a few.

Teaching for the major aims in addition to science content is a challenge. The challenge can, however, be met if the teacher:

a) chooses the curriculum emphasis to go with a given unit of required science content;
b) balances the range of emphases throughout students' science education;
c) evaluates student achievement on the basis not only of content but also of curriculum emphases.

B. Science Program Framework

Sections

4. Science Courses
5. Teaching Policy

Section 4

Science Courses

Science courses in Grades 7 to 12 and the OACs shall conform to the policies set out in this document and to the course descriptions outlined in Parts 2 to 15. Consideration should also be given to the features of the science program described in the following subsections.

4.1 The Science Continuum From Kindergarten to OACs

Students must see that science develops logically and continuously, from a broad overview to a progressively more specialized way of analysing the world. Teachers should be aware of the corresponding changes in the focus and aims of science education.

In the Primary and Junior Divisions the focus of science education is "the science and technology in the environment of the child",[4] and its aims are to have students "appreciate, understand, and relate to the science and technology in the world around them".[5] At this level science is not seen as a separate subject but as one component of a balanced and integrated program. The oneness of the students' environment is reflected in a *unified* educational experience.

By the time students reach the Intermediate Division, their experiences of the world have broadened to the point where unity gives way to diversity. Exploring this diversity thus becomes the natural focus of science programs at this level. Such a focus is also consistent with the principles, set out in OSIS, that "the program for Grades 7 and 8 should be characterized by breadth" (OSIS, subsection 3.4) and that "the program for Grades 9 and 10 is exploratory in nature" (OSIS, subsection 4.1). This guideline, therefore, makes provision for a *mosaic* of biology, chemistry, physics, and environmental science, in which students experience exploratory activities in each of these *diversified* but fundamental disciplines of science. The mosaic provides the opportunity for students to test their abilities in each discipline, confirm current interests or develop new ones, and formulate plans for more specialized study. They will also experience the reality that scientific processes and principles cross the artificial boundaries between the disciplines.

As the exploration of science becomes progressively more detailed, the diversified areas of the subject give way to *specialized* disciplines. Thus, science education in the Senior Division becomes subdivided into courses corresponding to these disciplines. Courses in biology, chemistry, environmental science, geology, physics, science in society, and technological science provide students with opportunities to study fields more closely corresponding to the divisions of science and technology encountered outside the school. In this way the science program contributes to the overall intent, set out in subsection 4.2 of OSIS, of providing students "with the best foundation for personal career and life aspirations".

4.2 Levels of Difficulty: Basic, General, and Advanced

OSIS suggests that "where circumstances permit and where the needs of different students can be accommodated by offering courses at two or more levels of difficulty, such levels should be offered" (subsection 4.6). The science courses described in this guideline for the different levels of difficulty in secondary schools are dissimilar and must be taught from different perspectives. If students wish to change their science programs from one level of difficulty to another, they should seek advice from members of the science and guidance departments. Arrangements may be made for such students to take transition courses (see OSIS, subsections 5.4 and 6.7).

Basic-level science. Basic-level science courses focus on the development of personal skills, social understanding, self-confidence, and preparation for the world of work. Students should perceive the academic knowledge and related hands-on activities required in basic-level courses as being applicable to their present and future lives. It should be apparent to them that the subject matter and inquiry processes in their science courses will help to prepare them to be successful individuals, independent but co-operative members of family units, and productive persons contributing to the general good of society. Science should help them to communicate effectively, inquire in a rational manner, exercise psychomotor skills, manage personal resources, respect the environment, maintain good health and fitness, and develop a constructive attitude towards employment and leisure.

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[4] Ontario Ministry of Education, *Science in Primary and Junior Education: A Statement of Direction* (Toronto: Ministry of Education, Ontario, 1986), p. 7.

[5] Ibid., p. 8.

Basic-level science courses are intended to present a mosaic of biology, chemistry, physics, and environmental science, all of which may be integrated. This blend is intended to help students develop an overview of science, a familiarity with scientific concepts and terms, job-related skills and attitudes, an understanding of social and environmental issues, and an appreciation of the role that science plays in their lives.

Teachers of basic-level science courses should teach more than science. From the subject material of such courses students should gain new insights about their bodies and related topics such as health, disease, cosmetics, nutrition, first aid, and skin care; about their homes and related topics such as gardening, clothing, furnishings, fibres and fabrics, and household physics and chemistry; and about their community and the region beyond through related topics such as leisure, sports, music, outdoor life, photography, the supermarket, tools, crafts, and space travel. Themes and topics such as these provide opportunities to meet students' personal needs to accept themselves, to relate to their families and friends, and to cope with the larger society of which they are important members.

General-level science. General-level science courses should prepare students for employment or for further studies in certain programs in the colleges of applied arts and technology and other non-degree-granting postsecondary educational institutions. The principal focus in general-level science should be on its practicality and its applicability to technology. Science should be perceived as personally useful and beneficial to society.

Many of the expectations in basic-level courses also apply to general-level courses. However, general-level science courses are oriented towards the disciplines of science to a greater extent, particularly in the Senior Division, with entire courses devoted to biology, chemistry, physics, or environmental science, and a technological science course that contains units of chemistry and physics. These courses are also designed to prepare students, through a variety of activities, to develop the habit of learning new skills and improving existing ones in the areas of problem solving, domestic management, consumer judgement, recreational achievement, personal fitness, and employment awareness.

General-level science courses must prepare students to listen, speak, read, and write with confidence and clarity in support of the language-across-the-curriculum expectations of the Ministry of Education. Resource-based learning should play an important role in this regard. Such courses should also relate science to practical ways in which students can prepare to participate as active and compassionate citizens in a democratic society. (Many of the societal implications mentioned in the units of study in general-level courses will provide opportunities to accomplish this.)

Mathematical work in general-level science courses should be at an appropriate standard and often related to financial or other practical aspects. Students might, for example, be asked to find out which is the least expensive of several kinds of electrical conducting materials, thermal insulating materials, nutritious diets, detergents, or antihistamines. Examples that relate science to students' lives should enrich the program.

Those students who plan to proceed to a college of applied arts and technology and enrol in specialized technological courses are advised to become proficient in the use of mathematics as it applies to chemistry and physics. This is especially true in regard to students in the following general-level courses: Applied Chemistry, Grade 11; Applied Physics, Grade 12; and Technological Science, Grade 12.

Advanced-level science. Many of the expectations for basic-level and general-level courses also apply to advanced-level science courses. The latter should, however, focus primarily on the development of academic skills and prepare students for entry to university or to certain programs of the colleges of applied arts and technology. Advanced-level courses should be designed to assist students to understand the theoretical principles, practical applications, societal implications, and substantive content of science. While the focus must be on academic preparation, activities that allow students to develop a variety of skills must be an integral part of any advanced-level science course. Through such activities students will experience the processes of inquiry for themselves, rather than simply learning the outcomes of the inquiry of others.

Advanced-level science courses that are enriched may be offered where desirable and feasible. The enrichment may apply only to some members of a class and may provide a way to stimulate and challenge gifted students and science enthusiasts. Particular care must be taken in evaluating the achievement of those students who take enriched advanced-level courses. OSIS states that "student achievement in such courses shall be reported at the advanced level so that all students taking an advanced-level course, whether it is enriched or not, will receive assessments based on comparable standards. This is particularly important when students submit their results to post-secondary institutions" (OSIS, subsection 4.6).

4.3 Science Courses and Credits

Grades 7 and 8. A science course is described in this guideline for each of Grades 7 and 8 (see Part 2). Each of these courses has been developed for a minimum time allocation of eighty hours. If the school's timetabling permits, they may be expanded to more than eighty hours through the extension of existing units of study over a longer period of time or the addition of locally designed units (in addition to the core units and prescribed number of optional units) that contain new subject matter that is not included in secondary school science courses.

These courses are considered to be fundamental preparation for secondary school science. Each student enrolled in Grade 7 or 8 is required to take a minimum of eighty hours of science unless the student is determined by an identification, placement, and review committee to be exceptional (see subsection 3.4, note f, of OSIS). It is recommended that exceptional students be encouraged to take Grade 7 and 8 science and that the courses be adapted to meet their individual needs. The courses may be enriched for capable students by incorporating topics from the section entitled "Possible Extensions" in each unit of study. The courses may also be adapted to suit the needs of students who cannot cope with all of the prescribed topics. "Good planning involves ... the identification of the different learning styles of individual students. Individuals vary in the ways they receive, process, and apply information. Teachers should be prepared to identify learning styles, needs, and abilities and to make adjustments to the program in order to accommodate them." (See OSIS, subsection 3.3.)

It is particularly important to analyse and to use effectively suitable learning materials when a course is adapted to suit special needs. Planning between the science teacher and teacher-librarian in the purchase and use of such materials is essential.

Grades 9 and 10. In the secondary school program two science credits are required as part of the sixteen compulsory credits that are needed for the Ontario Secondary School Diploma (OSSD). It is anticipated that the large majority of students will choose to take Grade 9 and 10 science to meet this requirement. (Some may prefer environmental science in Grade 10.) In order to retain the mosaic nature of the Intermediate Division science courses (the inclusion of biology, chemistry, physics, and environmental science), each of the following courses is to be offered only as a full-credit course within a single school year or semester: Science, Grade 9, General Level; Science, Grade 10, General Level; Science, Grade 9, Advanced Level; and Science, Grade 10, Advanced Level. Note that this ruling does not apply to basic-level Grade 9 and 10 science courses, in which the subject matter is less prescriptive and the teaching approaches are more flexible.

Grades 11 and 12. Science courses for these grades are indicated in table 1 in the introduction to this document. The following courses are prerequisites to the various science OACs:

- Biology, Grade 11, Advanced Level is a prerequisite to Biology, Ontario Academic Course.
- Chemistry, Grade 11, Advanced Level is a prerequisite to Chemistry, Ontario Academic Course.
- Physics, Grade 12, Advanced Level is a prerequisite to Physics, Ontario Academic Course.
- Any one of Biology, Grade 11, Advanced Level; Chemistry, Grade 11, Advanced Level; Environmental Science, Grade 12, Advanced Level; Geology, Grade 12, Advanced Level; or Physics, Grade 12, Advanced Level is a prerequisite to Science in Society, Ontario Academic Course.

Note that (a) the above prerequisites may be waived by a principal and (b) no other science courses shall be identified as prerequisites (see OSIS, subsection 5.6).

Note also that, since the Grade 12 geology course described in the guideline (see Part 11) may be taught under the aegis of a geography department as Geology (GGE4A) – note the course-code change – then either Geology (SGE4A) or Geology (GGE4A) may count as a prerequisite to Science in Society (SSO0A).

Ontario Academic Courses (OACs). Each of the science OACs – Biology, Chemistry, Physics, and Science in Society – is a one-credit, advanced-level, 110-hour course and cannot be implemented in segments for fractional credit values. Each OAC contains at least 80 per cent core material, which is intended to be consistent across the province. The balance of the course, if any, is to be selected from the optional units of study specified in the guideline.

The biology, chemistry, and physics OACs are specifically intended to prepare students for further work in science, engineering, medicine, and related fields. Students who anticipate entry into a university faculty that is science-oriented should ascertain which OACs in science are required for admission. They should also find out whether Science in Society, Ontario Academic Course can be used as one of six OACs required for entry into university. Although it may not necessarily prepare students for university science faculties, this course can provide a useful background for students who intend to pursue further studies in the arts, languages, law, finance, business, social sciences, and other non-science areas.

Since the Ontario Secondary School Diploma (OSSD) should represent some breadth of experience and not permit an overemphasis in any one subject area, students shall not be permitted to count more than three science OACs towards the earning of the OSSD. A fourth science OAC may be taken but shall count for credit only beyond the thirty credits required for the diploma.

Student achievement in each science OAC shall be evaluated in terms of the components listed in table 3, and these shall be emphasized proportionately as indicated. Further details on the evaluation of OACs are given at the beginning of section 14 of this document.

Table 3: Evaluation of Science OACs

Course Components	Percentage Range
Laboratory activities and reports	at least 15 per cent
Independent study	at least 10 per cent
One or more formal examinations	30 to 40 per cent
Term work not included in the above	the balance of the 100 per cent assigned to the course

4.4 Units of Study Within Each Course

Each of the courses outlined in this curriculum guideline contains a number of units of study. Each unit within a course is referred to as either "core" or "optional". For all students enrolled in any given science course, the core units are mandatory. The prescribed number of optional units is also mandatory, but there is some provision for choice among the optional units that are listed.

Each unit in each course contains a number of topics. The course descriptions in Parts 2 to 15 of this guideline suggest an order for the units and topics, but the order may be rearranged and the units and topics integrated to suit the needs of the students.

In most cases any given science course will build on the concepts and processes of previous courses. Where the same students enrol in two courses that are closely related and are offered concurrently, special care must be exercised in determining the order of topics and units so that the work in one course that is needed for the other course will be included in advance of the need. For example, this need would apply to the Grade 12 general-level applied physics and technological science courses.

4.5 Recommendations Regarding Course Selections

It is recommended that all students proceed through the secondary school science program by taking Grade 9 science as their first course, followed by Grade 10 science and/or environmental science, and then Senior Division science courses as desired. The following information is provided to acquaint students with the preferred routes through the secondary school science program.

1. Students who choose to work in science at the basic level are advised to attempt Science, Grade 9, Basic Level first. However, if they do not take or complete this course, they are permitted to take it later or to attempt other basic-level science courses in higher grades. This latter option may be particularly applicable for older students. It is recommended that science courses at the basic level be taken in sequence from Grade 9 through Grade 12, but this order is not mandatory.
2. Students who are successful in science at one level and wish to advance to the next grade in a higher level in the same discipline are generally advised to take a make-up transition course, unless they have performed exceptionally well. In such cases, personal guidance by the staff is advised. If a transition course is not available locally, such other avenues as independent study, a summer course, or a correspondence course may provide a suitable alternative.
3. Students who are unsuccessful in science at a given level of difficulty might choose one of the following options, particularly in cases where the credit is necessary to meet the compulsory requirements for the OSSD:
    a) drop science and qualify for an appropriate substitute compulsory subject for the OSSD (see OSIS, subsection 4.10, notes d and e)
    b) repeat the failed course
    c) take science in the same grade, but at a lower level of difficulty
    d) take a transition course, probably of thirty hours' or sixty hours' duration, that allows them to proceed in their science program at an appropriate level of difficulty (see OSIS, subsections 5.4 and 6.7)
4. It is recommended that, prior to taking any Senior science course, students take one or more science courses in each previous year at the same or a higher level of difficulty.

5. Applied Chemistry, Grade 11, General Level and Applied Physics, Grade 12, General Level should be taken prior to or at the same time as Technological Science, Grade 12, General Level. The development of this technological science course is based on the assumption that students who wish to take it will have had the background of the applied chemistry and physics courses. *Note:* Advanced-level Senior Division chemistry and physics courses may be used in place of the applied chemistry and applied physics courses respectively as preparation for the technological science course.
6. Students who are planning to take a number of technology or health-science courses at a college of applied arts and technology should seek recommendations from the colleges regarding secondary school science courses that will serve as an adequate preparation.
7. When planning their science programs, students are well advised to consider related subjects such as mathematics, computer studies, and technological studies. In particular, those students who select chemistry and physics should continue to pursue mathematics at the same grade level as their Senior science courses.
8. Students who are planning to continue studies in science or science-related areas at university should seek advice as to the most appropriate selection of Senior secondary school courses, particularly in such areas as language, mathematics, science, and computer studies. Secondary school science departments should make course recommendations to students but must not impose prerequisites beyond those stipulated in this guideline.

Section 5

Teaching Policy

5.1 Content and Process

Teachers are to design local science programs to include the acquisition and application of knowledge of the *content* of science and the development and application of skills in the *process* of science. Any science course in the Intermediate and Senior Divisions that gives undue emphasis to content over process or process over content fails to meet the aims of the science curriculum set out in subsection 3.1 of this document. To help teachers achieve the aims, knowledge and skill objectives are provided in the outline of each unit of study. Although these objectives are under separate headings, they are interdependent and complement one another. Attitudinal objectives are also to be woven into the fabric of the knowledge and skill objectives to underline the fact that science is a human endeavour. Since the fostering of attitudes is often intangible and difficult, attitudinal objectives are placed first in each unit of study. They are followed by the skill objectives to emphasize the need to provide time for their development. Finally, the knowledge objectives are listed, not because they are unimportant, but because they are too frequently overemphasized at the expense of other objectives.

Effectively designed local science courses, then, include what the student is (a) *to feel* – expressed by such words as the following: appreciation, interest, awareness, curiosity, concern, commitment; (b) *to do* – implied by such words as the following: process, skills, activities, experiences, investigations, inquiries, experiments, searching the literature, storing and retrieving data, solving problems; and (c) *to know* – identified by such words as the following: content, knowledge, topics, concepts, facts, laws, principles, theories, definitions, conventions, formulas. The objectives are written in behavioural terms.

Invariably, these three thrusts, feeling, doing, and knowing, if well balanced in the program, require the consideration of scientific applications and societal implications. It is essential that these components be integrated into the subject matter of all science courses designed from this guideline in order to provide a balanced relationship among the affective, psychomotor, and cognitive domains of learning and to relate science to the needs and issues of living.

5.2 Components in Each Unit of Study

Since it is essential that each course described in Parts 2 to 15 of this guideline contain well-defined objectives, specific content and processes, and relevance to the real world, the format used in each unit of study is consistent. Each unit contains the following subheadings, which are numbered as shown. Note that the first six components are mandatory parts of a unit of study.

1. Objectives: Attitudes, Skills, Knowledge
2. Student Activities
3. Applications
4. Societal Implications
5. Evaluation of Student Achievement
6. Safety Considerations
7. Possible Extensions
8. Some Teaching Suggestions

The cross references that are given in parentheses after an objective, student activity, application, or societal implication show the relationships among the various components in a unit. Such cross references are made only to material that follows the entry. They are not exhaustive and are not made between units or courses.

5.3 Teaching Policy for All Science Units

When interpreting the expectations of the Ministry of Education set forth in the course descriptions in this guideline, teachers shall adopt all mandatory components whenever a unit of study within a course is taught.

Each unit begins with an introduction, which describes the purpose for which the unit should be taught; other purposes may apply as well. The introduction also includes a list of topics, whose titles may be worded in other ways at the discretion of the teacher.

The unit *objectives* are classified under "Attitudes", "Skills", and "Knowledge" and express the expectations that shall be incorporated into the teaching of the unit. The objectives section is of primary importance and relates to all other components in a unit. It is the objectives that best describe the intended curriculum.

The *student activities* indicate the practical and laboratory work required of all students. Teachers may substitute *equivalent* activities where appropriate. Those activities that are to be actually performed by students themselves are marked with asterisks. If time and circumstances permit, the teacher should encourage students to do some or all of the unmarked activities as well. However, such unmarked activities may be demonstrated by a student or the teacher or may be discussed in conjunction with a textbook, film, computer program, or other learning material used as a resource. In any event, the scientific concepts and principles related to such unmarked activities and identified in the objectives of the unit of study shall be considered to be part of the prescribed course. (Note that correspondence courses offered by the Independent Learning Centre will not necessarily include all mandatory student activities.)

The *applications* and the *societal implications* outlined in each unit are to be included in all courses to illustrate the use and relevance of science and the interaction between science and society. These components should add interest and excitement to the subject matter. The number of examples to be included is indicated in each unit. Substitutes may be made where other examples of applications or implications become more appropriate than those listed in the guideline. It is not intended that these examples be dealt with in great detail. They can often be distributed here and there throughout a unit to illustrate the practicality and impact of science on society.

The "Evaluation of Student Achievement" section in each unit specifies the minimum percentage that shall be applied to certain mandatory forms of evaluation of the term work (exclusive of formal examinations). Teachers will often expand these minimum percentages. For the balance of the term mark, other forms of evaluation are encouraged and are to be administered at the discretion of the teacher. Evaluation must emphasize the philosophy of student exploration and problem solving and shall relate to the objectives, student activities, applications, and societal implications of the unit. The topic of evaluation is dealt with more fully in section 14 of this document.

The "Safety Considerations" section in each unit consists of suggestions that are designed to encourage safe laboratory procedures. The list of safety suggestions is not meant to be comprehensive, since the issue of safety is treated in detail in section 9 of this document. Instead, it is intended to highlight some salient points as a reminder.

The "Possible Extensions" section provides examples of optional material that might be included in the unit for capable students who work quickly and understand all of the concepts and processes required in the unit. Teachers may wish to consider such suggestions when enriching a course for gifted students and science enthusiasts. Students are not to be penalized for failure to achieve well in these extensions. Such extensions are intended to enrich and upgrade the quality of the learning experience. Normally, extensions are not to be treated as topics to be covered by all students within the time allocation for a unit. Only those students who can manage the regular work plus one or more extensions would be involved in such additional work. Such extensions may be implemented through a resource-based learning approach and individualized to suit the abilities of the students involved. They should be completed along with the regular work and within the time allocated under normal timetabling.

The section entitled "Some Teaching Suggestions" is intended to provide a few ideas to assist teachers in the delivery of each unit. As various units are implemented in the classroom, teachers are encouraged to adopt a variety of strategies beyond those mentioned in the guideline.

5.4 Time Allocations for Each Unit

In the course descriptions a specific number of hours has been allotted for the teaching of each unit in each course. These time allocations allow for teaching to all of the objectives, conducting the necessary student activities, and devoting some time to applications, societal implications, and the evaluation of student achievement. They represent the number of hours that should be spent on the respective units so that all core units and the designated number of optional units can be covered in the time available. The time allocations are to be considered as fairly rigid for advanced-level courses, slightly less so for general-level courses, and flexible for basic-level courses.

When a course is designed and implemented locally, there is a tendency to treat the first few units thoroughly and in too much depth. The last few units are then short-changed or omitted altogether. Teachers are to observe the time allocations as carefully as possible so that all units in a course are given balanced treatment.

The depth of treatment of any given unit must be based on the following factors:

a) the time allocation
b) the mandatory objectives
c) students' backgrounds
d) future courses that students might take in which further in-depth work will complement and continue the subject matter
e) students' interests, needs, and abilities
f) the amount of time required for mandatory and other suitable student activities
g) the emphases on special features such as language, career awareness, and sensitive issues
h) the expectations regarding homework
i) the time needed for the adequate evaluation of student achievement
j) the wise judgement of the teacher

Note: Each Grade 7 or 8 science course has a minimum time allocation of 80 hours; each secondary school science course is a one-credit, 110-hour course. The only exceptions to these time allocations for courses described in this guideline are those that may be offered in Grades 9 to 12 in the co-operative education mode (see subsection 13.2).

5.5 Locally Designed Units

Among the optional units in some science courses, the opportunity is provided to create a locally designed unit (LDU). Such units are included to allow for the presentation of a unit that may be of particular interest or relevance to a group of students. An LDU may incorporate any appropriate subject matter in science that the teacher(s) may wish to include and that is not contained in core units of future courses that students might take. It is to be designed for the time allocation indicated in the course description in this guideline and is to match the level of difficulty of other units in the course.

While an LDU is intended to be used as a means of introducing new content in the subject area or new work that expands on previous topics in the course, in *Senior Division courses only*, the amount of time allocated to the LDU may, instead, be used to extend the time allocations for core units.

Outlines of LDUs are to be submitted (in secondary schools, through the head of science) to the principal for approval and are to be kept on file in the school or board office. Each LDU outline should clearly identify the following: the unit's objectives – attitudes, skills, and knowledge; student activities; applications; societal implications; evaluation of student achievement; and safety considerations. Special strategies (e.g., field trips, resource-based activities, independent study) should also be included in the outline.

5.6 The Grade Placement and Naming of Local Science Courses

Each science course described in this guideline is associated with a specific grade in the Intermediate or Senior Division or is identified as an OAC. The name of the course and the course code indicate the grade for which each course is designed. Serious consideration should be given to the placement of each course in the school timetable. The courses have been labelled carefully and have been designed in order of increasing complexity and challenge with the intention of matching the abilities of students at their various stages of development.

Whenever it is beneficial and necessary, individual students or classes should be allowed to take science courses in years not normally associated with the grade designation. A Grade 11 course, for example, may be taken in a student's second or fourth year in high school and need not be restricted to the third year. Deviations from recommended grades should be allowed only in the best interests of the individual students concerned. The official provincial course codes must remain unchanged regardless of the year in which a course is taken. For example, if Physics, Grade 12, Advanced Level (SPH4A) is taught in Grade 11, the code used on the Ontario Student Transcript must remain as SPH4A and not be changed to SPH3A.

When student results are reported on the Ontario Student Transcript, the names of science courses shall be those shown in this guideline or those approved as non-guideline courses. The names of the guideline courses with their course codes appear in Appendix A.

5.7 Overall Policy for Science Courses

The following is a summary of the components that are expected to make up a science course based on this guideline.

Major features. Each course shall address the content and process of science through core and optional units of study. Each unit shall include objectives, student activities, applications, and societal implications (see subsections 5.1 to 5.3). Curriculum emphases shall be incorporated in order to blend curriculum aims with content (see subsection 3.4). The curriculum aims are identified as the aims of the science curriculum (see section 3) and these relate to the nature of science (see section 3, in particular subsection 3.1) and scientific literacy (see subsection 3.3). All aims in science are to be incorporated into science programs in order to achieve the goals of education (see section 2).

Special features. In addition to the major features listed above, all science courses under the framework of this guideline are to give attention to the following:

a) program adaptations for exceptional students (see subsection 6.2) and individualized instruction (see subsection 6.3) where these are deemed appropriate
b) life-management skills, employment awareness, sex equity, multiculturalism (see subsections 6.4 to 6.7), and the achievements of Canadian and other scientists
c) language development (see section 7)
d) measurement, predominantly in the SI metric system (see section 8 and Appendixes B and C)
e) instruction and awareness related to safety (see section 9 and the precautions mentioned in each unit of study under the heading "Safety Considerations")
f) values education related to science (see section 10)
g) evaluation of student achievement (see section 14 and the requirements in each unit of study under the heading "Evaluation of Student Achievement")

C. Special Features of the Science Program

Sections

6. Considering the Science Student
7. Language and Science
8. Measurement
9. Safety
10. Values in Science Education

Section 6

Considering the Science Student

6.1 The Image of the Successful Science Student

The student of science, whether or not he/she aspires to be a scientist or technologist, should acquire the following characteristics:

a) an interest in natural phenomena and technology
b) an ability to understand scientific concepts and the nature of science
c) a capability for applying investigative processes and manipulating laboratory apparatus
d) a capacity for the retention of scientific and technological knowledge
e) mathematical expertise
f) some resourcefulness and creativity in learning
g) a comprehension of the language, vocabulary, and symbols of science
h) a sense of self-worth and a respect for other people's ideas and opinions
i) acuity in distinguishing fact from fiction
j) a willingness to apply learnings in science to everyday life
k) a developing sense of ethical values that relate to scientific advances and increasingly sophisticated technology

Students will have these characteristics to varying degrees and can develop them further through their study of science. The general aim underlying all of the science courses outlined in this guideline should be the attainment by students of scientific literacy, an aim for which each science teacher should strive.

Since students differ greatly in their abilities, interests, and needs, a variety of delivery modes must be considered in designing the local science program. The rest of this section deals with issues related to different kinds of learners in science courses.

6.2 Program Adaptations for Exceptional Students

Science is a subject that affords many students who have special learning needs with a great variety of experiences and learning opportunities that focus on themselves and the world in which they live. However, the kind, breadth, depth, and pace of learning experiences for exceptional students in science courses should correspond to their needs, abilities, interests, and aspirations. To determine what adaptations should be made to any science course for an individual exceptional student who has been identified by the school board's identification, placement, and review committee (IPRC), the following approaches should be used:

1. The teacher should be made aware of the specific needs related to the area of exceptionality of the student: behavioural, communication, intellectual, physical, or multiple. That is, the special learning needs of the student should be clearly identified by the IPRC and conveyed to the teacher if at all possible well in advance of the commencement of a course. Such information is usually recorded in the Ontario Student Record Folder.

2. The student should receive the best possible advice concerning the level of difficulty at which any particular science course should be taken.

3. The teacher and student should discuss adaptations to the course that are in the best interests of the student. The student should be clearly instructed as to the objectives that are to be achieved and perhaps those from which he/she may possibly be exempted.

4. The teacher should realize that many exceptional students, given ample time and consideration, learn in much the same way, have the same ranges of ability, and generally desire to participate in the same manner as do other students. Teaching strategies that work well with non-exceptional students generally work well for the exceptional student; the latter, however, will require more personal attention.

5. Teaching strategies must be tailored to meet the particular needs of exceptional students with regard to:

    a) input: how the subject matter is presented to them, keeping any special modifications in mind;
    b) their processing of subject matter: how the learning tasks are to be performed in light of their exceptionalities;
    c) their output: how their achievements are to be evaluated.

6. Individual teaching strategies must match the particular needs of the exceptional student. Co-operative planning with the teacher-librarian should prove beneficial in helping the science teacher to adopt special strategies. Other educational resource people may need to be involved as well in particular cases. The following are examples of the kinds of adaptations that might be necessary:
   a) A student may require a special focus on concrete materials, hands-on activities, multisensory experiences, and laboratory and field work.
   b) A student with a hearing impairment may be helped by films, diagrams, extra reading, and the use of other visuals.
   c) A student with a visual impairment may be helped by the use of audio input, models, tactile experiences, or a buddy system.
   d) A student with an orthopedic impairment may require accommodation for his/her wheelchair in the laboratory and may require a special warning about safety precautions.
   e) An exceptional student may be paired with a classmate who can be a mentor in the laboratory or assist him/her in a tutorial manner.
   f) A hard-of-hearing student taking a unit on acoustics might be given an alternative assignment or be assigned a literature search on an area that is relevant to the laboratory work of other students.
   g) Oral tests and examinations may be arranged for students who are handicapped in writing skills.
   h) Gifted students may be able to extend their work in creative ways through additional inquiry, problem solving, independent study, and participation in special science projects. Topics from the "Possible Extensions" component of each unit of each course can be used for enrichment within the specified time allocations for the units of study.

7. Special care should be taken in all science courses in which exceptional students are enrolled to ensure that all such students are thoroughly familiar with and able to implement all safety precautions during laboratory work. If a handicap would cause a laboratory procedure – for example, using concentrated acids – to be hazardous, then the student concerned should be paired with a responsible student or be exempted from the activity and given some substitute work. (See also section 9, "Safety".)

8. The teacher should be reasonably sure that the exceptional student can cope with the course objectives that have been chosen and adapted to suit the student's needs and abilities. This may mean providing additional aids and resources and allotting sufficient time not only for the student to complete a specific task, but also for the teacher or mentor to evaluate the student's success. The assistance of additional professional or paraprofessional staff and the use of specialized equipment or facilities may be required.

9. The teacher should consider a variety of evaluation techniques. For many exceptional students with handicaps, evaluation is most rewarding if done frequently and for very short portions of the course. Constant, sincere feedback, combined with consideration and encouragement, will strengthen the student's sense of achievement and self-worth. (See also section 14, "Evaluation".)

10. The expectations of teachers with regard to exceptional students should be such that the students do not gain a sense of inferiority or superiority or sense that they are being treated in a demeaning manner or with special favour.

11. Teachers should be aware of and familiar with the following publications of the Ministry of Education, which contain suggestions on teaching strategies for pupils with various exceptionalities:
    - *Children With Physical Handicaps and Health Impairments* (1978)
    - *Children With Communication Exceptionalities* (1979)
    - *Children With Mild Intellectual Handicaps* (1979)
    - *Children With Moderate and Severe Intellectual Handicaps* (1981)
    - *Programming for the Gifted* (1985)
    - *Children With Learning Disabilities* (1986)
    - *Behaviour* (1986)
    - *Special Education Monograph, Number 3: Exceptional Pupils With Mild Intellectual Handicaps in Secondary Schools* (1986)
    - *Vision* (1987)

Adaptations to a science course for an exceptional student must be made, then, in the best interests of the student, but also with respect for the integrity of the subject. The suggestions below are made to give examples of ways in which the courses set out in this guideline may be adapted for students with handicaps. These suggested alterations apply only to exceptional students and not to others who are enrolled in science. Possible changes may be made by:

a) limiting the optional units to permit more time for core units. This does not apply to basic-level courses where there is only one core unit in each course;
b) selecting a number of identified objectives or student activities from each of the units within a course;
c) spreading the more difficult or theoretical work over several units or all units rather than omitting an entire core unit or two that may be essential to the student's further studies;

d) deleting a few of the required applications and societal implications that may not be relevant to the student;
e) omitting or adapting some of the requirements for the evaluation of student achievement in some units.

In general, the integrity of any science course is expected to be maintained as fully as possible in accordance with the intent of this guideline. However, it is better to encourage all exceptional students to take science and adapt courses to suit their needs than to discourage them through rigid conformity to an inflexible program.

6.3 Individualized Instruction

A program in which students, with the assistance of the teacher, determine their own rate of progress is referred to as "self-paced". Such programs may be particularly applicable to courses at the basic level of difficulty and courses that are adapted for exceptional students, but they are possible in other situations as well.

In a typical or traditional mode, all students in a class are expected to cover a topic or unit in the same length of time and then move on to the next area of study. The time for instruction is fixed, and students' comprehension and mastery vary widely, as do their marks.

With individualized instruction, the comprehension of content and the mastery of processes become the primary objectives, and the time taken per topic or unit will vary considerably from one student to another. Objectives, in the form of evaluation items, are predetermined, and students master a specific minimum percentage, for example, 85 per cent, before going on to the next area of study. Students work at varying rates and often in small groups. If a student delays unduly over a specific area, either the objectives are altered or the student moves on for a while and then returns to try again. No student is kept marking time needlessly. Students who progress ahead of others may be stimulated to take on further enrichment work. More capable students may act as mentors or tutors to slower ones. In some cases the objectives and how they are to be achieved may be specified in a contract, which the student aims to fulfil.

To ensure that a student can master a high proportion of the objectives prescribed in a course, the prescription for individualized learning should ideally be determined very early by a joint conference between the teacher and the student. Expectations regarding what is to be mastered and in what length of time the work is to be completed, along with approaches to the assignment, must be worked out mutually and be clearly understood. In some cases changes may be made to course objectives. For example, in Grades 7 and 8, where courses are not designed at various levels of difficulty, a class might contain some slow achievers who are not classified as exceptional but for whom a few of the objectives are inappropriate. Teachers, at their own discretion, may limit such objectives. However, care must be exercised to ensure that the secondary school science programs of these students are not jeopardized.

The following should all be part of self-paced learning based on personalized instruction planned by the student and the teacher:

a) individual or small-group work. Groups can be changed from time to time and may be homogeneous or heterogeneous depending on expected outcomes;
b) the use of special resources to provide direction. These may consist of study guides in the form of modules complemented by support materials, programmed booklets, audio-tutorial materials, and computer programs that simulate scientific processes and problems. Since independent investigations can motivate students to do outstanding projects, the teacher-librarian should work with the science teacher to provide resources and opportunities for students to work in the school's resource centre;
c) a variety of learning activities. Students might perform investigations, complete reading assignments, view videotapes and films, listen to cassettes, work in the school's resource centre, use a computer program, engage in co-operative education, participate in a short-term work experience, and react with the teacher, other students, and relevant persons in the community;
d) fundamental core expectations along with a variety of optional extensions that can be used to enrich the core and yet permit individual choice assisted by guidance from the teacher;
e) frequent assessment, to ensure that students have mastered each unit before they proceed to further work;
f) feedback from the student to the teacher on the subject matter and the learning strategies for the various modules or units of work. In this way the program can be assessed and improved.

Individualized instruction has often proved to have beneficial results. Research[6] indicates that such instruction can:

a) ensure greater student participation;
b) encourage more acceptance of responsibility;
c) stimulate an increased desire for self-evaluation;
d) often provide as much coverage of the subject matter over the length of an entire science course as does a non-individualized program;
e) frequently lead to students' gaining a positive attitude towards themselves, others, the school, the subject, and education in general.

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[6] Richard S. Marchese, "A Literature Search of Review of the Comparison of Individualized and Conventional Modes of Instruction in Science", *School Science and Mathematics* 77:8 (December 1977): 669-703, and Ronald D. Simpson and Norman D. Anderson, *Science, Students, and Schools* (New York: John Wiley and Sons, 1981), p. 314.

An individualized instruction program may take several years to develop. At first, it may be used along with conventional methods and may form only a small part of a student's course. Eventually, the proportion of the course handled in this way may become the dominant part of the course. While individualized instruction will be demanding of the science teacher involved, when a student succeeds through this method, the results will be rewarding for both the student and the teacher.

6.4 Life-Management Skills

The science program offers students numerous opportunities to develop skills and abilities that they will find useful in managing their everyday lives, both while they are in school and in the future. Teachers should emphasize such skills from time to time to stress the point that science education is for everyone, not just potential scientists. Science provides a way, even with its limitations, of thinking about the world we live in, our place in it, and the influence we can have on it.

Naturally, there are many other ways of perceiving humanity and our place in space. In the blend of perspectives derived through science and other subjects in the curriculum, students can formulate their own view of life, tempered by family, religious, community, environmental, national, and even international influences.

The following are some of the life-management skills that can be enhanced through science:

a) *communication skills:* learning to communicate in a science environment, using the language of science, and sharing the societal implications of science and technology with the non-science community (see also section 7, "Language and Science")
b) *process skills:* learning to observe, sense, compare, seriate, classify, measure, estimate, describe, predict, infer, investigate, inquire, experiment, collect, organize and process data, illustrate with drawings, graph, manipulate equipment, design strategies, control variables, evaluate, synthesize, solve problems, interpret, explain, theorize, and understand conceptual schemes
c) *computation skills:* learning to use simple mathematics to solve problems in science and daily life, including cost analysis, measurement, unit analysis, and time management. (This also includes facility with calculators and computers.)
d) *consumer skills:* learning to analyse advertisements, examine quality statements, understand the economics of science, and appreciate science-related consumer applications and societal implications
e) *interpersonal skills:* learning to get along with others, share a common task, be considerate to those who are handicapped, care for the common good (for example, in conserving energy), and listen to and be willing to consider other viewpoints
f) *technological skills:* learning how to understand how things work, how they can be repaired, and how they affect individuals and society as a whole
g) *health skills:* learning how to maintain physical and mental fitness, understanding nutrition and hygiene, knowing about infection and disease, realizing the effects of drugs, appreciating the need to control pollution, and respecting the health and welfare of other people, plants, and animals
h) *job-preparation skills:* learning to organize time efficiently, establish priorities, do a good day's work, perform well, excel at times, respond in a conscientious manner, be honest, accept criticism, assume responsibility, evaluate one's own work, and be aware of employment opportunities and related qualifications
i) *research skills:* learning how to learn; how to collect, process, and retrieve data; how to find sources of information; how to think through a problem; how to differentiate between essential and extraneous matter; how to verify a conclusion; how to determine whether a former "truth" is still valid; and how to present the results of an investigation in a clear and concise manner

6.5 Employment Awareness

In addition to dealing with subject matter and processes, science courses should assist students to acquire a general awareness of career opportunities and characteristics in the field of science and related technology. Students should be encouraged to think about vocational and professional careers in science and to consider the wide variety of ways in which many jobs relate to or support science-oriented employment. A growing number of careers and job opportunities now require a fundamental knowledge of science, and this trend is expected to continue well into the next century. Many traditional jobs are being replaced by high-technology employment. The successful preparation of students to make wise career choices in the sciences or related fields is one of the major aims of science education today.

A career-education program in science should provide students with opportunities to acquire the following:

a) good work habits
b) acceptable interpersonal skills
c) basic academic knowledge and skills applicable to various kinds of scientific pursuits
d) an understanding of employment requirements that involve scientific knowledge and skills

e) decision-making skills
f) the ability to analyse and solve problems of a scientific or technological nature
g) familiarity with practical applications of science and its societal implications

When introduced here and there in the regular science program, career education not only heightens student interest in studies that otherwise might seem irrelevant but also enhances the teacher's awareness of the many dimensions of students' lifetime needs. Most of the units in the science courses described in this guideline contain references to employment awareness; these should be woven into the program of instruction at points where they are appropriate and relevant for students. Science classes themselves should be designed to reflect modern expectations with regard to businesslike work habits, positive attitudes, and an appreciation for appropriate dress and conduct.

The science teacher's role is to plan, in co-operation with teachers of other subjects and with the school guidance department, instructional strategies for science-career education that complement the overall aims of the science program. Such strategies might include the following:

a) science classes devoted to career preparation when appropriate
b) field trips to investigate science careers
c) invitations to scientists to visit the school and speak about their work
d) case studies of the careers of Canadian and other scientists
e) student interviews of those working in science-related careers
f) student surveys of science-related careers in their community
g) maintenance of a science-career resource centre
h) the choice of a textbook that includes material on employment awareness
i) films that deal with careers

The preparation needed for science-related jobs should be discussed with students. Both girls and boys should be encouraged to consider future scientific or related technological employment. Personal aptitudes, interests, and abilities might be examined in relation to such career opportunities.

Science teachers should deliberately encourage students to investigate science-related work in business, industry, and education through resources such as the following:

a) the occupational files in the Student Guidance Information Service (SGIS) and its related computer data bank
b) CHOICES (Computerized Heuristic Occupational Information and Career Exploration System)
c) school guidance counsellors
d) colleges and universities and their calendars
e) local businesses and industries
f) professional science associations
g) science periodicals
h) the news media, particularly science programs on television
i) science museums and centres

In addition, work-experience programs and co-operative education involvement are an excellent means of exposing some students to the work done by scientists and technologists (see subsection 13.2 of this document).

6.6 Sex Equity

Science courses based on this guideline are to have equal applicability and appeal to male and female students. Teachers must examine their expectations concerning student achievement and ensure that they are free of sex-role stereotyping. A good science program should not permit any assumptions based on gender. Instead, schools should provide both girls and boys with equal access to opportunities to develop their individual potential through science and should provide a variety of experiences without restrictions imposed by sex-related expectations regarding behaviour, interests, abilities, and traits.

The scarcity of female role-models in the educational system in positions of responsibility and their underrepresentation in the science classroom in particular have a limiting effect on the career aspirations of female students.

The gap between a girl's career *aspirations* and *expectations* is vividly described in the following excerpt from *Who Turns the Wheel?* (Science Council of Canada, January 1982, p. 82):

> A girl might aspire to be a lawyer but expect to be a typist in a law office; she might aspire to be a pharmacist but expect to be a checkout clerk in a drug store; she might aspire to be a doctor but expect to be a nurse.

Recent studies indicate that, although students are innately similar regardless of sex, girls frequently come to believe through family and peer influences, classroom activities, and teacher expectations that they are incapable of rational thought processes, mathematical competence, and scientific achievement. Teachers, knowingly or otherwise, because of their own cultural expectations and childhood experiences, may encourage unwarranted sex-differentiated attitudes towards levels of achievement in science.

Numbers of traditionally female-oriented jobs are being replaced or reduced by the computer and robotization. As a result, women will have to compete for skilled technological occupations that have often been held by men or that are now developing as new forms of employment. Such jobs require computer skills and a basic understanding of mathematics, science, and technology.

Who Turns the Wheel? indicates that girls and young women, all too often, have received inadequate encouragement and counselling at home, in the schools, and in the community. The document points out that according to the stereotypical image the scientist or engineer is very intelligent, highly techno-oriented, and male. While this sex inequity is changing, teachers have a great responsibility to do all they can to avoid perpetuating this behavioural pattern and to counteract it by positively reinforcing a dynamic vision of the capabilities that women have and of the contributions they can make in scientific pursuits and technological activities. Teachers must encourage both girls and boys to recognize that both women and men can, and that many should, participate actively in the life and physical sciences.

Teachers must analyse their own attitudes and expectations for possible stereotypes concerning the capabilities and aspirations of boys and girls in mathematics, science, and technology. The fostering of sexual equality through unbiased curricula, teaching methods, resource materials, evaluation practices, and guidance roles should be a deliberate and vital part of the educational process. Above all, teachers must develop in students – both male and female – a positive sense of self-worth, a capability to solve practical problems in daily life, and a mastery of skills that will lead to personal satisfaction and preparation for career selection.

The following suggestions should be useful to science teachers as they seek to ensure sexual equality in the classroom:

1. Students should have an opportunity to work with a variety of laboratory partners. When members of the opposite sex are paired, the partners should alternate in accepting the more active and more passive roles. It is also important, at times, to pair students of the same sex together. Both sexes should encourage one another to adopt all roles without any sex discrimination.
2. The curriculum should be designed to appeal to both sexes, and examples, applications, and societal implications that have been traditionally associated with males, females, and both sexes should be used. Time can be well spent discussing why some societal or vocational activities have been traditionally male or female and what might be done to provide for a better balance.
3. Learning materials should be carefully selected to reinforce sex equity.
4. Questions should be posed impartially to boys and girls regardless of subject matter or degree of difficulty; for example, difficult questions related to technology should not be directed solely towards boys or girls.
5. Non-sexist language should be used. Students should be helped to discern bias in language and to restate a sex-stereotyped expression in a non-sexist manner.
6. Both girls and boys should be provided with ample opportunity for three-dimensional visualization, the development of psychomotor skills, and the acceptance of responsibility for organizing the work, making decisions, and maintaining safety precautions in the laboratory.
7. Girls as well as boys should be encouraged to participate in science projects, science fairs, field trips, technological courses, mathematics courses, computer exercises, industrial visits, work experience, linkage, and co-operative education wherever appropriate.
8. Teachers should discuss with counsellors and parents ways and means to help both girls and boys overcome their fear of science and mathematics and actively encourage enrolment in these subjects, as well as in computer studies and technology.
9. Students should be made aware of the value of science and science-related employment and should be provided with specific examples of vocations and work opportunities throughout all science courses at the Intermediate and Senior levels. Girls as well as boys should be encouraged to think about the possibility of careers such as electrician, technician, technologist, traffic controller, nurse, doctor, engineer, and scientist.
10. Students should be helped to realize that a knowledge of science can be most beneficial in maintaining fitness, in understanding how things work, in solving problems in everyday life, in appreciating the environment, and in contributing to the welfare of society.
11. Examples of contributions made by women in science should be included in the program. In addition, female role models in the community may be asked to communicate their perspective to science classes.
12. Female students should be encouraged to consider the possibility of entering the teaching profession through a specialization in science.

6.7 Multiculturalism

"The province of Ontario has a tradition of providing opportunities for people of various cultural, linguistic, racial, and religious origins to build a life together as Canadians" (OSIS, subsection 2.8). Schools are to demonstrate their commitment to this principle at all times. For example, biology classes will discuss a wide variety of topics in genetics, and sensitivity must be exercised by teachers and students when dealing with racial characteristics. Teachers can use both the genetic differences as well as the close similarities of all individuals to identify the genetic uniqueness of individuals as well as the equality of all population groups.

There are also groups that hold to particular food laws and customs, certain health and medical practices, various religious convictions, and a variety of collective beliefs. Some of these views influence the way in which such groups may approach some topics in science. Teachers should treat all topics in a sensitive and scientific manner and do whatever they can to ensure that all students are both respected and respectful. (See also section 10, "Values in Science Education".)

Many of the suggestions made in the previous section on sex equity can also be applied in the context of multiculturalism and race relations. All school boards should conscientiously and sensitively examine their policies and practices in science to ensure that there is a positive and constructive approach to areas that have racial and cultural implications.

Section 7

Language and Science

7.1 Language Skills

"Language is the means by which individuals process experience and give meaning to it, both for themselves and for others."[7] The processes of science – identifying problems, developing hypotheses, organizing data, explaining findings, proposing theories, and formulating generalizations – are all language-intensive activities. Thus, science both provides an opportunity for the development of language skills and requires facility with language for an understanding of the subject.

Students should be provided with regular opportunities to develop each of the language skills of thinking, listening, speaking, reading, and writing as they relate to science. Their language skills should go beyond the fundamental use of spelling and grammar, with the sophistication expected in each skill increasing as students move through the Intermediate and Senior Divisions and varying with the level of difficulty of the program.

Since students learn by example, science teachers should constantly serve as good role models in the use of appropriate language skills.

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[7] Ontario, Ministry of Education, *Language Across the Curriculum*, Curriculum Ideas for Teachers, English, Intermediate Division (Toronto: Ministry of Education, Ontario, 1978), p. 3.

Thinking skills. Having students respond to a variety of kinds of questions will help them develop their thinking skills. Questions should range from those requiring simple answers to those demanding higher-order thinking skills, as illustrated in the following sequence:

1. Name a renewable energy resource.
2. Make a list of at least eight energy resources and classify them as renewable or non-renewable.
3. In your opinion, what alternative energy source would be most effective in this country? Defend your answer.

Although these questions require written answers, a discussion or debate of the questions will ensure that students do more than copy the answers from a pamphlet or book on energy. More thinking can be accomplished in less time if students engage in oral problem solving in pairs or groups.

Listening skills. Students can develop these skills through following oral instructions, formulating answers to oral questions, discussing expressed observations and conclusions to experimental work in laboratory groups, and participating in discussions about scientific applications and societal implications. They can also listen to oral presentations by the teacher or to tapes, records, films, and videos. Small-group discussions provide greater opportunities for students to speak and express ideas and to listen and react than do whole-class discussions. The former are also less threatening to students and can be monitored by the teacher, who can circulate among the groups to develop language and problem-solving skills.

Speaking skills. These can be developed through laboratory work, small-group activities, and whole-class interaction. Oral reports, seminars, debates, and other student presentations, such as those involving problem solving, provide further opportunities for skill development. Students should be encouraged frequently to express their own ideas and to explain concepts in their own words. Their explanations might then be analysed and rephrased in a clearer and more accurate manner. The emphasis should be on communication, rather than merely on speaking.

Reading skills. These can be developed through a variety of reading tasks. The purpose of any reading assignment must be clear. It may be to determine a main idea, to find supporting details for an argument, to make notes on key points, or to summarize the essentials of a passage.

Teachers should teach students how to read science materials, which differ from narratives. For example, sequence is important to carrying out an experimental procedure. The discussion of new science terms, with their distinct and well-defined meanings, should be part of the process. Magazines and popular books as well as texts and reference books should be made available to students. Teachers should determine the readability of materials and use only those that are appropriate. The study of scientific papers and articles provides students with opportunities to learn about scientific writing and the use of formal references.

Writing skills. Students' skills in this area can be improved through careful attention to their notebooks and written projects. Students should record their observations, draw conclusions, and express ideas and concepts in their own words. The objectives to be achieved in writing science notes and reports should be made clear to students, who should gradually be permitted to become more selective and independent in their writing. The different techniques required in writing a laboratory report should be taught. As students progress through the grades, they should be capable of recording more detailed observations and of using a greater variety of language in reporting on their work. They can develop their skills through writing science reports on laboratory work, scientific theories, factual data, practical applications, or societal implications and through writing extended explanations. Science teachers should take the responsibility for teaching students how to write a good report and should identify the criteria used to evaluate written work. Science courses should also provide some opportunities for creative writing. For example, laboratory reports should not always follow the same format.

The writing skills of students can be analysed – with sensitivity – when answers are presented on the chalkboard. This allows opportunities for the entire class to share collectively in the response and to compare it with their own written answers at their desks.

Students should be introduced to the construction and interpretation of graphs, diagrams, and model solutions of mathematical problems and should be made aware of the value of these in presenting information clearly and precisely.

7.2 Assignments and Evaluation

The out-of-class time required to complete written assignments that involve *extensive* written reports must be justifiable by the opportunities that the assignments offer for new and significant learning. Such assignments should be designed to allow for a wide range of ability levels. They should adequately challenge capable students but should avoid unduly high student-anxiety levels for those who are less capable. This latter group may need to be encouraged by performing short and interesting assignments. In general, students should be able to complete assignments by referring to the resources that are available within the school library resource centre, the science classroom, the home, or a convenient local library.

Frequent short writing assignments are preferable to occasional long project reports or papers. Flexibility in the length of short assignments should be permitted; for example, they might vary from 200 to 500 words. This requires students to make decisions about the planning of suitable reports.

Assignments should be designed to discourage bad practices such as plagiarism, recycling of others' work, tedious "busy work", and the purchase of others' writings. All assignments should have the potential to enhance the image that students have of their own abilities.

In regard to the writing of laboratory reports and science assignments, variety in format and style rather than slavish adherence to a single prescribed format should be encouraged. A prescribed format for some assignments may be necessary initially to establish good procedures and to teach students to follow instructions and to organize their writing so that it can be readily followed by others. However, the lack of freedom to be creative can lead to boredom and negative compliance. Scientific writing, including laboratory reports, can be varied and interesting. The use of headings, colour, underlining, and spacing should be flexible, provided students' work is clear and well organized. The typing of assignments should be optional.

When evaluating student achievement in science, the teacher should take language development into account, assessing students' thinking, listening, speaking, reading, and writing development. If any one of these components is neglected in the evaluation process, students will tend to ignore the development of the corresponding skill. Student assignments are useful for purposes of diagnostic and formative evaluation (see section 14, "Evaluation"). Notebooks should also be evaluated on a regular basis to ensure that students are developing the ability to write legibly and accurately and to organize their written work so that it is useful for study and review.

An overuse of objective tests, for example, those that consist mainly of multiple-choice items, minimizes the opportunities for students to demonstrate their writing skills. Homework assignments, tests, and examinations should include both restricted items and extended-response essay items that challenge students to interpret information and to think critically. (See section 14.)

7.3 English Vocabulary in French-Immersion Science Courses

French-immersion science courses for Anglophones are naturally taught in French. This means that the scientific and technological vocabulary in English will not normally be required of students. However, because English is the pre-eminent language of science and because students may have to take subsequent science courses in English, it is recommended that a simple glossary or list of equivalent scientific words in English be available to students in the science classroom. This is particularly important in a discipline such as biology, where the vocabulary is comparatively extensive.

7.4 Immigrant Students

Immigrant students who have not attended Ontario schools and who are not thoroughly familiar with English will benefit greatly from the study of science because it is an excellent vehicle for developing language skills through the use of concrete and visual materials and through the interactive nature of the laboratory activities. As well, the fact that many scientific and technical terms are somewhat similar in various languages to those used in English should prove helpful in communicating with immigrant students.

Many immigrant students will not speak English as their first language, and others may speak a dialect of English. For such students some modification of courses is necessary and expected. For example, the subject matter can be adapted to retain the key concepts while eliminating some supporting detail.

Science teachers can implement the following suggestions to ensure that existing laboratory materials and methods, as well as science learning materials, are appropriate for immigrant students.

1. Important ideas should be put in writing. Students can review these ideas later or translate them with the aid of a bilingual dictionary.
2. Visual material (e.g., pictures, charts, graphs, films, filmstrips) should be used to develop content and conceptual background material.
3. The experimental process should be emphasized. Students from other countries may have had a non-experimental science education and may not have been taught processes such as observing, classifying, inferring, hypothesizing, predicting, generalizing, and supporting conclusions.

4. Provision should be made for new students to synthesize information from books, magazines, laboratory manuals, handouts, and other reference materials. In many parts of the world memorization from a single source is emphasized.
5. Immigrant students should be paired with speakers of fluent English as laboratory partners. Such partnerships can be mutually beneficial as a result of the sharing of both experiences and learning.

It may be advisable to provide some new students with special training in English prior to placing them in the science program. It is important to allow them to enrol as soon as possible in science courses at the level of difficulty at which they would normally work if they were familiar with the language. Since immigrants face a new environment and, in all likelihood, a new language, the value of science in helping them appreciate, understand, and question the world around them cannot be overemphasized. Also, science-related applications, implications, and employment in Ontario should be carefully explained in the science program.

Section 8

Measurement

8.1 Estimation

Estimation can be an effective learning experience. The estimation and measuring of a physical quantity often requires an understanding of the property to be measured and of any techniques that may need to be applied. Thus, students who cannot make reasonable estimates may lack a clear understanding of many quantitative physical characteristics.

Often, students' rough estimates reveal to a teacher the degree of their comprehension. For example, when students make quantitative reference to the area of a pond, the length of a paramecium, the volume of a rock, the density of sand, the speed of a toy vehicle, the force exerted by a magnet, the energy used to lift a pail of water, the rate of growth of a plant, or the temperature changes when hot and cold water are mixed, their answers help the teacher to determine whether they do or do not understand the quantitative concept involved. Thus, the student who can pick up several different solids of varying sizes and arrange them in order of density has developed a good conceptual grasp of volume, mass, and density. For this reason, students should adopt the habit of estimating results prior to taking measurements or to performing calculations based on measurements.

"Fermi" questions are a good way of promoting conceptual thinking or problem solving through estimation. (Enrico Fermi, a renowned physicist, was fond of challenging his students to test their powers of estimation and related problem solving.) In responding to such questions, students try to estimate the answer to a question to the nearest power of ten and then justify their answer.

The following are examples of Fermi questions that might be posed in secondary school science:

a) What is your approximate volume in cubic centimetres?
b) About how many hairs do you have on your head?
c) Roughly how many dried peas are there in this jar?
d) How many ping-pong balls would fill this room if it were emptied of all furniture and fixtures?
e) How many undertakers are there in a city like Toronto with a population of about two million people?
f) How many slices of bread will you eat by the time you are seventy years old?
g) How many bricks are there in that building across the street?
h) How many refrigerators are there in Canada?

Questions such as these should be used on an occasional basis to stimulate students' thought processes and their use of problem-solving techniques and to promote discussion and creative debate. They can also be used to introduce similar kinds of problems faced by scientists (e.g., How many caribou are there in Canada? How many Canadians have cancer? How many molecules are there in a given volume of gas? How many hectares of land are affected by acid rain?).

8.2 Metric Units and Physical Quantities

The system of measurement to be used in science courses is the one that is now adopted predominantly in science on an international scale. The system is called the International System of Units, which is abbreviated SI in all languages. (SI comes from the name *Système international d'unités*, which was adopted by the General Conference on Weights and Measures in 1960.) It is sometimes called the SI metric system.

The further science students advance, the more they can be expected to use SI units. However, they should not be pushed too far too soon; they should be permitted to use everyday units for some purposes. In limited situations where progress in Canada's metric conversion has been slow, imperial measures may still be mentioned in science courses. For example, it might be suggested that copper wire be wound around a 2½ inch nail in an experiment in electromagnetism. To call such a nail a 64 mm nail could result in unnecessary complication until metric nail sizes are adopted.

This means that while Canada is still undergoing metric conversion, science teachers are expected to use SI units (and those units that are permitted for use with the SI) predominantly but not necessarily exclusively in their teaching. This must not be interpreted as permitting teachers to use imperial units indiscriminately or to put off the use of SI metric units unnecessarily. For all scientific problem solving, SI metric is to be used as much as possible, but now and then in a practical application, reference may be made to imperial units where such units are still in general use in Canada.

The Intermediate and Senior science courses do not have specific units of study on measurement and the metric system. It is recommended that measurement be blended into the curriculum and that SI units be taught whenever it is appropriate to do so. At such times students should be engaged in measurement activities.

The following schedule should be treated as a rough guide in developing the topic of measurement in the science program.

By the end of Grade 8, students should be expected to be familiar – as much as possible by active experience – with the following common metric units and their symbols:

a) the metre, kilometre, centimetre, and millimetre
b) the square metre, square kilometre, square centimetre, square millimetre, and hectare
c) the cubic metre, cubic centimetre, litre, millilitre, and kilolitre
d) the kilogram, gram, milligram, and tonne or metric ton
e) the second (and the minute, hour, day, week, and year, which are permitted for use with SI)
f) the degree Celsius
g) the kilometre per hour as it pertains to travel

They should also recognize the decimetre and know that a litre has the same volume as a cubic decimetre and that a millilitre has the same volume as a cubic centimetre. Students in Grade 8 should also be familiar with and understand the newton and the joule.

By the end of Grade 10 most students should be thoroughly familiar with the decimal nature of the metric system and be able to use it with facility in the everyday world. Their knowledge of metric prefixes should have been expanded to include *micro-* as in *microsecond* and *mega-* as in *megagram*. Many students, particularly those working at the advanced level, will understand density units such as the kilogram per cubic metre and the gram per litre; the specific heat unit, the joule per kilogram degree Celsius; and the unit of frequency, the hertz. The fact that a litre of water has a mass of one kilogram and that a millilitre has a mass of one gram should be familiar to most Grade 10 graduates, who should leave the Intermediate years with a simple and useful, but not overly sophisticated, overview of the metric system.

Science students in Senior courses should have some knowledge of the structure of SI, including an understanding of what is meant by "base units" and "coherently derived units". Senior students, particularly those working at the OAC level, should be familiar with those primary units that pertain to the course they are taking. Such terms include the following: metre, kilogram, second, kelvin, ampere, and mole; square metre, cubic metre, and kilogram per cubic metre; hertz, metre per second, and metre per second squared; newton, joule, watt, pascal, kilogram metre per second, and newton metre; coulomb, volt, and ohm; degree Celsius, joule per kelvin, and joule per kilogram kelvin; kilogram per mole and joule per mole; and becquerel and gray. Senior science students should also know that SI prefixes range from *atto-* to *exa-*.

The majority of Senior students should know why a common former metric unit such as the calorie is not a coherent unit and therefore not part of SI. They should also realize that a number of non-SI units are permitted for use with SI; these include such units as the minute, hour, day, and year for measuring time and the degree, minute, second, and revolution for measuring plane angles. In addition, some non-coherent units with special names are accepted; these include the litre, hectare, and tonne for everyday and commercial purposes.

In some Senior courses reference should also be made to other permitted non-SI units such as the electronvolt, unified atomic mass unit, nautical mile, knot, and astronomical unit.

The following units are among those that have become obsolete and are no longer to be used in science courses, even though they may still appear in books and periodicals: the angstrom, micron, are, stere, kilogram-force, dyne, torr, millimetre of mercury, bar, standard atmosphere, calorie, erg, mho, curie, and rad. *Note:* Here *rad* refers to the formerly used unit of ionizing radiation now replaced by the gray (1 rad = 10 mGy). The symbol for the radian, a unit used to measure plane angles is also "rad"; the radian is included in SI.

Secondary units are those that are denary multiples or submultiples of the primary units and that are formed by means of metric prefixes. Many of these are also permitted for use with the SI and are often useful in practical work.

Physical quantities such as length, mass, force, pressure, electric current, temperature, and density are concepts that are often used to make quantitative descriptions of physical phenomena. Each physical quantity has a reference quantity, called the unit (e.g., the reference quantity for length is the metre). Any other quantity in this category can be expressed as a product of a number and this unit; the number is called the numerical value of the quantity, for example, 1 km = 1000 m.

Physical quantities are designated by names and *sloping* symbols in printed material. (These quantity symbols are not explicitly part of SI.) Units are designated by names and *upright* symbols. Examples are given in table 4.

Table 4: Physical Quantities, Units, and Their Symbols

Physical Quantity	Quantity Symbol	SI Unit	Unit Symbol
length	l	metre	m
mass	m	kilogram	kg
volume	V	cubic metre	m^3
time	t	second	s
temperature	t T	degree Celsius or kelvin	°C K
force	F	newton	N
momentum	p	kilogram metre per second	kg·m/s

The chart of physical quantities and corresponding metric units in Appendix B includes many of the quantity symbols recommended for use in Canada. The symbols shown are those indicated in the *Canadian Metric Practice Guide*. Some of the symbols are taken from the Greek alphabet, and teachers of Senior advanced-level science courses should use them as shown, particularly in the OACs. In courses in the Intermediate Division it may be more appropriate to use symbols from the English alphabet in lieu of Greek symbols (e.g., D, rather than ρ, for density).

For a full treatment of metric units refer to the latest edition of the *Canadian Metric Practice Guide* (CAN3-Z234.1). In order to prevent confusion or ambiguity in the use of quantitative expressions, there are recommended editorial practices that are to be adopted in science courses. Many of these are listed in the *Metric Editorial Handbook* (Z372-1980). Both the guide and the handbook are available from:

Canadian Standards Association
178 Rexdale Boulevard
Rexdale, Ontario
M9W 1R3

In addition, Appendix C lists a good number of recommendations for metric usage. Science teachers should use and teach the correct metric style whenever physical quantities are expressed. Many former practices should be discontinued and replaced with accepted practice. Some examples are listed in table 5.

Table 5: Examples of Metric Style

Accepted Practice	**Incorrect or Unacceptable Practice**
6 h	6 hr
1800 r/min	1800 r.p.m.
15 A	15 amps
2-L flasks or 2 L flasks	2 L-flasks
two litre-flasks or two 1-L flasks	2 L-flasks
kilometre per hour	kilometre/hour
3 × 5 (for multiplication)	3·5 (for multiplication)
6 m/s^2	6 m/s/s
J/kg	J per kg
3 Mg or 3 t	3 kkg
$0.75	$.75
cm^3	cc or c.c. or cu.cm.
He gained a few kilograms.	He gained a few kg.

8.3 Accuracy and Precision

There are differing views on the handling of numerical answers in exercises involving physical quantities. The recommendations regarding the treatment of significant digits and rounding off as stated in this section are derived from the *Canadian Metric Practice Guide* and apply to Intermediate and Senior science courses in the schools. See the end of subsection 8.2 in this document for the source of the guide.

Accuracy. *Accuracy* means "the conformity of an indicated value to an accepted standard or true value". The difference between an observed value (or the average of observed values) and the true value is called the *inaccuracy* or *error*. The magnitude of this difference is an indication of the "accuracy". The smaller this difference becomes, the smaller the inaccuracy and the greater the accuracy.
Example: The true time is 15:28:36, that is, a little before three-thirty in the afternoon. If I say the time is 15:29:46 and you say it is 15:29, you are more accurate than I am. My version of the time has a greater error than yours.

Precision. *Precision* means "the quality of being sharply defined or stated". Precision is sometimes indicated by the number of significant digits expressed in a measurement or the size of the unit involved. More commonly, precision is indicated by the number of significant digits to the right of the decimal marker.
Example: I state that the time a lightning flash occurred was about 15:30; you state that it was at 15:28:50 to the nearest five seconds; and Mary states that the time was 15:28:52 to the nearest fifth of a second. Your time was more precise than mine (more significant digits), and Mary's was the most precise (a smaller and more precise unit of measure). Actually, it would, in this case, be possible for me to be more "accurate" than the others. If, for example, we found out later that we had set our timepieces by a clock that was three minutes slow, then my observation would have a smaller error and be more accurate than the others, but the other observations would still be more precise.

For purposes of school science, *precision* shall be gauged by the number of digits to the right of the decimal, that is, the number of decimal places. (This criterion applies once a unit of measure has been selected. Changing the unit and making a corresponding change in the position of the decimal marker obviously does not alter the precision; for example, 53.41 mm is just as precise as 5.341 cm.)
Example: 5.341 cm is a more precise measurement than 281.42 cm, even though the latter contains more significant digits. The first measurement has three decimal places, whereas the second has only two. The first is precise to the nearest one-thousandth of a centimetre; the second is less precise, since it is expressed only to the nearest one-hundredth of a centimetre.

Significant digits. Significant digits are those digits in the numerical value of a measurement that are consequential to its precision. For purposes of this guideline and the courses that are designed under its framework, the following rules are to be adopted:

1. In the expression of the numerical value of a physical quantity, the significant digits are to be identified as follows:
    a) The digits 1, 2, 3, ... 9 are significant.
    Example: 363.2 m or 0.3632 km each have four significant digits.
    b) Any zeros to the left of the first non-zero digit are not significant.
    Example: 3.4 mL or 0.0034 L each have only two significant digits.
    c) Zeros embedded between other non-zero digits are significant.
    Example: 205.007 kg has six significant digits.

d) Any zero printed or written to the right of a non-zero digit is to be taken as significant unless some information to the contrary is given.
Example: The quantity 3600 m may be considered as containing four significant digits; however, there remains the element of uncertainty. If, in fact, the zeros are not significant because the measurement was made to the nearest 100 m, then the zeros should be omitted. This can be done by using a larger unit of measure or expressing the amount in exponential form as in 3.6 km or 3.6×10^3 m.
When any right-hand zeros are significant, they should be shown as in 36.0 km or 36.0×10^3 m or 3.60×10^4 m (with such zeros written to the right of the decimal marker).

2. If a measurement is expressed several times in the same unit, then the greater number of significant digits indicates the greater precision.
Example: In referring to a person's temperature, 37.3°C is more precise than 37°C.
A measurement made with an instrument having a more finely divided scale has the possibility of giving a more precise measurement.

Manipulation of numerical data. In multiplication or division, the result after rounding off should contain the same number of significant digits as are contained in the number in the computation that has the fewest significant digits.
Example: 85 N × 25.75 m = 2188.75 J
= 2.2×10^3 J or 2.2 kJ (rounded to two significant digits)

Note: Rounding off should be applied at the end of a multistage calculation, not part way through. This should not require tedious work, since students should be permitted to use calculators or computers.

In addition or subtraction, the result after rounding off should be as precise as the least precise of the measurements used in the computation.
Example: 3.012 m
28.39 m
16.5 m
7.81 m
55.712 m = 55.7 m (when rounded to one digit after the decimal marker)

Rounding off. When a number is to be rounded off, the following rules are to be observed.

1. When the first digit discarded is less than five, the last digit retained is not to be changed.
Example: 17.3482 kg rounded to three digits is 17.3 kg.

2. When the first digit discarded is greater than five, or if it is a five followed by at least one digit other than zero, the last digit retained is to be increased by one.
Example: 6.9361 km rounded to three digits is 6.94 km.
8.25501 ha rounded to three digits is 8.26 ha.

3. When the first digit discarded is five, followed only by zeros or no digits, the last digit retained is to be increased by one if it is odd or left unchanged if it is even.
Examples: 2.375 t rounded to three digits is 2.38 t.
2.385 t rounded to three digits is 2.38 t.

Numbers that are exact counts, or declared by definition, are considered to be perfectly precise, as are defined fractions. Such numbers do not influence decisions regarding the rounding off of a final result.
Examples: The average mass of three people having masses of 63.8 kg, 59.2 kg, and 69.7 kg is [(63.8 + 59.2 + 69.7)/3] kg or 64.2 kg. The "3" in this problem is an exact count.
3629 mm = (3629/10) cm = 362.9 cm. The divisor is exact and cannot be considered to have only two significant digits.
The fraction in $E_k = \frac{1}{2}mv^2$ has no influence in rounding-off.

Standard notation. The use of standard notation in Senior Division science courses is to be encouraged but need not be insisted on for all answers.
Examples: Standard notation for 3400 J is 3.40×10^3 J or 3.40 kJ when rounded to three significant digits. However, answers such as 0.3 kg or 16 N might best be left unchanged unless there is a good reason to do otherwise.

Measurement errors. All measurements involve a margin of error. Students should realize that:

a) the accuracy of a measurement is limited by the measuring device selected and the manner in which the device is used;
b) the accuracy of a measurement is usually indicated by the number of significant digits and its precision is commonly indicated by the number of decimal places;
c) the result of a calculation based on measurements is not more accurate than the least accurate measurement;
d) sources of error in an experiment should be considered by those conducting the activity and minimized if accuracy is important.

Note: Work on topics such as percentage error, percentage difference, and mean deviation is not specified under this guideline. However, such topics should be included in the OACs at appropriate points.

Teaching expectations. The teaching of such concepts as significant digits and rounding off in science courses should be co-ordinated with the teaching of those topics in mathematics. For both subject areas the following procedure is recommended.

In Grades 7 and 8 simple rounding techniques are to be employed. Students will need to be informed about the number of significant digits or the number of decimal places that are to be retained. This applies particularly when students use calculators. Students need not be expected to decide on their own the degree of accuracy that is desirable.

In rounding off, students may find the following slogan helpful: When the dropped digits are:

- below 50 ..., round down;
- above 50 ..., round up;
- on 50 ..., round even.

The exception occurs in business and consumer applications where monetary values are rounded according to the traditional practice of the institution transacting the business (e.g., 5% of $12.50 may be taken as 62 or 63 cents).

Students in Grades 9 and 10 should know and apply simple rules for rounding off when adding and subtracting and when multiplying and dividing. The use of exponential notation and standard form for expressing answers should be encouraged but not made mandatory.

In Grade 11 and beyond students should be able to apply all rules for rounding off correctly and also be able to state answers in standard form when it is sensible to do so.

The recommendations stated above for secondary school courses apply to advanced-level science courses. They may be adapted to suit the needs of students in general- and basic-level courses.

8.4 Formats in Solutions to Problems

Care must be exercised when students provide mathematical solutions to problems. Statements must be accurate and make sense. The following shows two possible formats for the same problem.

Example: A student measures a strip of metal 1.5 m long, 2.8 cm wide, and 8.5 mm thick and wishes to find the volume.

In *mathematics* symbols usually denote numbers without physical units, and a solution to the problem above may appear as follows:

Length of strip = 1.5 m = 150 cm $l = 150$
Width = 2.8 cm $w = 2.8$
Thickness = 8.5 mm = 0.85 cm $d = 0.85$
$V = lwd$, where V represents the number of cubic centimetres of volume
$= 150 \times 2.8 \times 0.85$
$= 357$
Hence, volume $= 3.6 \times 10^2$ cm^3 (to two significant digits).

In *science* quantity symbols usually represent physical quantities, including their units. This means that each quantity symbol represents a numerical value with an associated unit. The solution to the above problem should therefore appear as follows:

$l = 1.5\,\mathrm{m}$
$w = 2.8\,\mathrm{cm}$
$d = 8.5\,\mathrm{mm}$
$V = lwd = 1.5\,\mathrm{m} \times 2.8\,\mathrm{cm} \times 8.5\,\mathrm{mm}$
$= 150\,\mathrm{cm} \times 2.8\,\mathrm{cm} \times 0.85\,\mathrm{cm}$
$= 357\,\mathrm{cm}^3$
Hence, $V = 3.6 \times 10^2\,\mathrm{cm}^3$ (to two significant digits).

Students should be familiar with both types of solution as a result of their mathematics and science courses. Teachers of these subjects should recognize the validity of either method and should co-operate in their support for both methods. At the same time, students must not be permitted to state inaccuracies such as $V = 150 \times 2.8 \times 0.85 = 357\,\mathrm{cm}^3$, because $357 \neq 357\,\mathrm{cm}^3$.

In science courses, particularly in the Senior grades, it is recommended that solutions to problems indicate the units throughout the entire solution to each problem. If the solution to a problem becomes too complex because of the inclusion of units within the solution, such units should be shown to the right of the appropriate line of numerical values.

Section 9

Safety

It should be noted that this section on safety is not exhaustive. School boards are responsible for being up to date and alert in matters of school safety. The following sections are intended to be helpful to science teachers, who are advised to become familiar with safety precautions and to do all they can to instil safety awareness in students. Note that subsection 12.1 of this document also contains information on safety in the laboratory.

9.1 Safety in the Laboratory

General requirements. Subsection 236(j) of the Education Act requires the principal of the school "to give assiduous attention to the health and comfort of the pupils" and subsection 21(g) of Regulation 262 under the Education Act states that the teacher shall "ensure that all reasonable safety procedures are carried out in courses and activities for which the teacher is responsible". Safety in the laboratory involves the prevention of accidents by people through planning and proper performance. It demands the deliberate development of appropriate attitudes and actions.

A wide variety of laboratory chemicals, biological materials, physics apparatus, and environmental components are potentially dangerous unless students are taught how to handle them. Regulations and directives governing accident prevention, information on the use of potentially harmful substances, and statements outlining safety policies and procedures are available through resources such as the following:

- the Occupational Health and Safety Act
- safety memoranda published by the Ministry of Education
- school board and local school documents or handbooks on safety
- this guideline section on safety
- the subsection entitled "Safety Considerations" in each unit of each course description in this guideline
- information that appears in periodicals, journals, and textbooks

Teachers and students are to perform experiments in science courses. This involves some element of risk. Safety skills are to be developed so that the possibility of accidents is minimized. The science activities to be performed as an essential part of science education are to be carried out with full regard for the safety of all concerned.

Students are to be informed by teachers of possible risks that they might encounter. For example, when students use fluids from their own bodies, such as saliva (in which cheek cells have been collected) or blood (when blood typing), they are to experiment only with their own fluids. Under no condition whatever should a body fluid be transferred directly or indirectly from one student to another. Students who are haemophiliacs are not to be required to do blood typing, but should be given the opportunity, when appropriate in a science course, to examine prepared slides of blood cells.

Students' hands are to be washed thoroughly with soap and water after handling body fluids. Equipment such as cover glasses and slides should be rinsed after they have been disinfected by being placed in water with a 10 per cent household bleach for twenty minutes. Although the risk of infection is low, these precautions are suggested as advisable.

Teachers are expected to instil in their students a positive attitude towards safety through a responsible common-sense approach. Safety instructions are to be given early in each course and then constantly emphasized throughout the year or semester. The best method of developing responsible safety awareness in students is through the example and guidance of the teacher.

Responsibilities of administrators. School board administrators should:

a) keep the board informed about safety policies and insist that high priority be given to accident prevention;
b) ensure that principals, science heads, and science teachers have copies of the board's safety guidelines or handbook, where such documents exist;
c) facilitate the work of the board's Joint Health and Safety Committee by providing principals and science heads with up-to-date information and by outlining the board's expectations in regard to safety practices and procedures;
d) assist principals and science heads in correcting any violations of or departures from the board's safety guidelines;

e) distribute Ministry of Education safety memoranda pertaining to science to all science teachers;
f) require teachers to attend safety seminars and workshops to ensure up-to-date knowledge and procedures related to accident prevention;
g) ensure that science teachers have up-to-date information about toxic and hazardous chemicals and their storage, use, toxicity, corrosivity, hazard ratings, disposal, flammability, and related first-aid measures;
h) ensure that courses of study address the matter of safety;
i) distribute to science departments pertinent bulletins on laboratory usage and the legal liability of teachers;
j) arrange a procedure for the periodic disposal of hazardous and outdated substances from the schools;
k) require the regular inspection of laboratories and their utilities by qualified experts;
l) seek to ensure that science facilities are constantly adequate and safe;
m) provide directives for safety procedures in the event of specific emergencies.

Responsibilities of principals. Principals in each school should:

a) support the administration in implementing all board safety policies related to students in science, with particular attention being given to students with disabilities (see subsection 6.2, point 7);
b) ensure that seating in science rooms meets fire regulations;
c) see that supply teachers for science are properly informed regarding safety in the laboratory;
d) assign numbers of students to laboratories with full regard for building codes and student safety;
e) expedite the repair or replacement of deficient laboratory safety features or equipment;
f) avoid assigning non-science classes to science laboratories and science classes to standard classrooms;
g) rule that students are not permitted in science storage or preparation rooms without permission from a science teacher.

Responsibilities of teachers of science. Teachers are expected to exert a positive influence on students by teaching safety through precept and example. They should seek to develop in their students:

a) an awareness of and alertness towards safety at all times;
b) the constant application of safety procedures during all activities;
c) a constructive criticism of experimental procedures, particularly those that could be hazardous;
d) a willingness to design and carry out safe experimental procedures;
e) an ability to take responsibility for safety during all activities in the laboratory.

Teachers should:

a) caution students regarding any potential hazard before attempting an experiment, ensure that there is no form of "horseplay" in the laboratory, and never leave students unsupervised in the laboratory during a student laboratory activity;
b) test all experiments and any new products or untried substitutes involved before students are permitted to participate in an activity; have students make a safety check of apparatus before using it; see that all chemical containers are labelled properly and that the manufacturer's instructions are followed carefully; and, prior to the use of a chemical, ensure that students know how to transport, handle, clean up, dispose of, and safely store the chemical;
c) require that students use appropriate safety equipment, such as individual protective eyewear, and make sure that it is maintained in good repair; ensure that the laboratories are equipped with safety equipment such as fire extinguishers, fire blankets, a fire pail and clean, dry sand, eye-washing facilities, and a complete first-aid kit; and teach students how to use the safety equipment;
d) be familiar with the routine to follow in case of an accident and, on the first appropriate school day, instruct students on what to do in case of emergencies in laboratories; be knowledgeable about first-aid treatment and the personnel in the school who can be called on for assistance with first aid; and have readily available, for immediate reference, information on first-aid and emergency procedures;
e) refrain from performing or allowing students to perform experiments that could readily produce a serious hazard for which protective equipment is not available or for which first aid cannot be provided;
f) be informed of the health problems (e.g., allergies) of students and of their possible need for special allowance or exemption during specific kinds of experimental work or field trips;
g) attend periodic safety seminars and workshops.

Scientific knowledge plays a vital role in laboratory safety. Although students learn by experimenting, any student activity must be judiciously directed. Only those activities where students are fully aware of possible hazards and their prevention are to be assigned to them. They must be impressed with the importance of following instructions exactly, the need to understand what they are doing, the reasons for maintaining order in arranging equipment, and the absolute necessity to ask for advice when in doubt.

Teachers must give complete and exact directions and have them fully obeyed. They must ensure that experiments are conducted in logical, organized steps, while avoiding unnecessary movement or crowding in the laboratory.

The ultimate aims in regard to safety are to prevent accidents and to enable students to engage in scientific investigations and experimentation, to design their own techniques with confidence, and to enjoy their participation in the process of doing and learning science without fear of injury. (See also subsection 9.2, "Some Recommended Safety Procedures".)

Responsibilities of students. Students shall be expected to:

a) become familiar with general safety precautions early in each science course;
b) adopt safety measures during all student activities;
c) know the location and correct use of safety equipment;
d) use protective eyewear and other safety devices when required;
e) wash their hands after working with chemicals, biological specimens, and micro-organisms;
f) maintain a clean and uncluttered work area;
g) tie back loose clothing and long hair when working near open flames or machinery;
h) refrain from leaving lighted burners unattended, consuming any food or drink in the laboratory, and bringing butane lighters into the laboratory;
i) report to the teacher all accidents, no matter how minor; broken equipment; damaged or defective facilities; and any unknown, unlabelled, or suspicious-looking chemicals.

Students shall be clearly informed that, without teacher supervision, they are never to:

a) taste chemicals or other materials;
b) transport dangerous materials;
c) remove glass tubing from or insert it into rubber stoppers;
d) handle any apparatus, chemicals, live animal specimens, or poisonous plants;
e) conduct experiments;
f) enter science storage or preparation rooms.

9.2 Some Recommended Safety Procedures

The following are examples of safety procedures that should be carried out regularly in science laboratories. They are recommendations of the Safety Committee of the Science Teachers' Association of Ontario.

1. Equipment such as burners, flasks, beakers, cylinders, and any potentially dangerous or fragile equipment that could be hazardous if tipped over is to be secured. This can be done by means of stands, clamps, and various types of holders.

2. Whenever there is the possibility of flame, splash, explosion, or implosion, the apparatus is to be surrounded with shields or mesh screens. For example, a eudiometer can be surrounded with a lucite shield.

3. Equipment must be used only for the purpose for which it was designed. Unsuitable substitutes are not to be permitted. The following equipment should be used:

   a) round-bottom flasks for reduced pressure;
   b) proper types of tongs for crucibles, test tubes, and beakers;
   c) CSA (Canadian Standards Association), UL (Underwriters' Laboratories of Canada), or other officially approved electrical apparatus;
   d) hand protectors for handling glass tubing.

4. Proper techniques are to be used for laboratory activities. The following are some examples:

   a) Acid must be added slowly to water, not water to acid. Acid must also not be mixed with chlorine-bearing compounds (e.g., powdered or liquid bleach that has been used to clean a sink).
   b) Pipetting should never be done by mouth, only by means of a safety bulb.
   c) Anyone carrying out an activity involving chemicals, open flames, or moving machinery should do so in a standing position.
   d) Test tubes that are being heated must be pointed away from all persons and should be covered by a spurt cap.
   e) Boiling chips should be used in the heating and refluxing of liquids.
   f) Tasting should occur only under the explicit direction of the teacher.
   g) In microbiology, sterile equipment must be used, and disposable plastic containers must not be reused.
   h) Electrical cords must be maintained in excellent condition and must be removed from sockets by the plug, not the cord.

   i) Light from a laser or ultraviolet lamp must not be allowed to enter the eye directly.
   j) All persons must be shielded from radioactive or X-ray sources.
   k) Gas cylinders must be secured, and regulators must not be exchanged.

5. Excess chemicals, products, cultures, lancets, and other materials must be disposed of properly with due regard for safety and in many instances in accordance with government regulations. The following are a few examples:
   a) Broken glass should be kept separate from other types of waste and must be deposited in a well-marked container.
   b) Chemical waste should be placed in special, well-labelled containers or disposed of according to the directions of the teacher.
   c) Left-over chemicals should be converted to a safe form by neutralization, dilution, or other reaction.
   d) Solutions of heavy metals should be precipitated or evaporated to dryness.
   e) Hazardous wastes must be disposed of in a manner consistent with government regulations.
   f) Biological cultures should be autoclaved or incinerated in a closed incinerator or by other accepted methods.
   g) Preserved specimens should be incinerated.

6. Harmful gases, unless properly vented, should be contained in properly designed, closed systems or be rendered safe by neutralizers.

7. All persons in the laboratory, including the teacher, must be amply protected as follows:
   a) The eyes, face, and body must be protected with adequate protective wear.
   b) Long hair must be tied back.
   c) Loose clothing must not be allowed in the laboratory; it is to be tied back so that it does not present a hazard.
   d) Bare feet are not allowed, and the wearing of open-toed shoes is to be discouraged.
   e) Students are to report allergies and to take related necessary precautions.
   f) Gloves are to be used when hands may be endangered.
   g) Unnecessary contact with animals is to be avoided.
   h) Students are to be restricted in the handling of poisonous plants or plant parts.
   i) Students are not to have free access to stock bottles of chemicals.

8. Chemical-reaction hazards are to be minimized through the use of semi-micro or small quantities of chemicals. Unused chemicals must be disposed of safely, not returned to stock bottles.

9. A plan of action should be developed to deal with emergencies involving fire, explosion, escape of a dangerous gas, chemicals, electrical hazards, bodily injury, or the need for evacuation. These emergencies require a knowledge of the location and use of the following: fire alarms, extinguishers, fire blankets, and fire pail; first-aid kits; shut-off valves and switches; eye-wash facilities; chemical neutralizers; spill-control materials; and escape routes.

10. Good housekeeping procedures conducted before, during, and after all laboratory activities prevent many hazards from developing. Common sense and awareness of safety should prevail in all science classes.

9.3 Animal Care in Science Courses

A responsible attitude towards living things. The humane care and considerate use of all animal life is a concern in any ethical and conscientious society; it is a major responsibility for those individuals who use animals for experimental purposes.

Teachers of science have a responsibility to develop in their students a respect for living things and an understanding of the conditions necessary for their well-being. To this end, living organisms should be available to be studied and cared for by students. Students should learn their responsibilities towards living organisms and should be involved in their care and maintenance. They should take pride in their ability to maintain animals and plants in a healthy state and in a proper environment for which they, the students, are responsible. Today's emphasis on the environment makes it imperative that students experience the environmental necessities for maintaining life. The principles of animal care related to such variables as nutrition, cleanliness, space, exercise, and temperature can be compared with the principles governing the maintenance of human life with dignity in a proper environment.

Teachers also have a responsibility towards the students who work with animals in the laboratory. This applies to animals that are dead or alive. Diseases such as ringworm, rabies, and salmonella can be transferred from animals to humans. All bites and scratches inflicted by animals should be treated professionally. After handling animals, students are to wash their hands thoroughly with soap and water. It is recommended that living animals (vertebrates) be examined by a veterinarian to ensure that they are healthy specimens before they are used in the science room.

The Animals for Research Act and Ontario schools. This act deals with animal care. It is comprehensive legislation providing for the comfort and well-being of all vertebrate animals in research. "Vertebrate" includes birds, fish, salamanders, and snakes, as well as such other common classroom residents as mice, rats, and guinea pigs.

Research is defined in the act as "the use of animals in connection with studies, investigation, and teaching in any field of knowledge". This is a broad definition; hence, the Animal Industry Branch, Ministry of Agriculture and Food, is concerned not only with the use of animals in university, industrial, diagnostic, and institutional laboratories, but also with the use of animals for teaching in elementary and secondary schools and with the experimental use of animals at science fairs. In the same way, the term *research facility* is a comprehensive one, and every establishment, however small or large, that uses animals for studies, investigation, and teaching comes under the jurisdiction of the legislation.

Ontario schools have been exempt from registration as research facilities under the act, as well as from some of the regulations concerning room construction and procurement of animals; however, all other relevant portions of the act and its regulations apply to school and home animal projects.

The Animals for Research Act requires that every research facility or school that has or uses live animals during the school year come under the jurisdiction of an "animal-care committee". The animal-care committee is a peer committee. It may be made up of any number of persons. The qualifications of the animal-care committee members are not specified, with the exception that one of its members must be a veterinarian. Animal-care committees may be composed of teachers, consultants, supervisors, and persons outside the education system, such as lawyers and animal-care technicians.

A local animal-care committee is appointed by one or more school boards. The animal-care committee is responsible to the public through the Animal Industry Branch; thus, a peer-government control system is being developed.

The initial task of the animal-care committee is to assemble, review, and approve animal-project proposals in the schools under its jurisdiction. The animal-care committee has the initial responsibility in the enforcement of the "pain clause" (see below) and may order that any project cease or not be proceeded with.

Animal-care committees will control the character of animal utilization in schools in their area. It is expected that they will develop a standard list of animal projects that teachers in their area can use without the need for further approval. Any teacher or supervised student who wishes to deviate from the standard procedures would be required to submit a separate project proposal for approval.

The "pain clause" requires that no animal suffer unnecessary pain. The regulations do not clarify, grade, or specify a measure for pain. It is the task of the local animal-care committee to determine what is suitable for its community, schools, grades, and students. It is recommended that, in determining whether a project is suitable and necessary, consideration be given to the following:

a) the age, background, and ability of the student, and the capacity of the student to benefit from the experience;
b) the total group of activities of which the animal project is a part;
c) the preparation of the student and the follow-up lessons;
d) the scientific design and the merits of the project;
e) the merits of an alternative use of non-sentient materials (including audio and visual aids) or lower forms of living material;
f) the background of the teacher or supervisor in relation to the proposed project;
g) the level of competent supervision by teachers or qualified persons in the related field.

Ideally, these facts are best determined at the local level by teaching peers and the community through the local animal-care committee.

In addition, the animal-care committee has responsibilities concerning the activities and procedures related to the care of animals, the standards of care and facilities for animals, and the training and qualifications of persons who are engaged in the care of animals in schools. In carrying out these responsibilities, the committee should be able to identify a nucleus of trained personnel, resource material, and local expertise that will be available to assist teachers with animal projects, animal care itself, and animal-care equipment.

The act and its regulations touch on all aspects of animal care and use. The regulations are general in nature and, in most cases, refer to the health, welfare, and comfort of animals. The regulations discuss light, ventilation, temperature control, feed and water, cage requirements, and cage cleaning and care. Euthanasia procedures are well defined. Amphibians, reptiles, non-human primates, and dogs and cats receive further attention in special sections in cases where their needs are not fully met by the general regulations.

The enforcement of the act and its regulations is through the animal-care committee, spot inspection of schools, investigation of complaints, and inspection of science fairs by veterinarians and animal-health technicians.

Under the Animals for Research Act inspectors assist the Youth Science Foundation in monitoring the use of animals in science fairs in Ontario. The application of the act in regional science fairs has indicated that the peer-government system of control can achieve desirable results at the preuniversity level.

The aim of the act is not, as some people have feared, the abolition of the use of animals in schools, but rather the proper maintenance and use of animals that are in the schools or involved with school-related projects. Both teachers and students must be conscious of the fact that today's students may have moral and legal responsibilities for animals in their future studies or work; this early experience with proper animal care, proper animal use, and legislation is a necessary part of education. The Animals for Research Act and its regulations are available from:

The Director
Animal Industry Branch
Ministry of Agriculture and Food
Guelph Agriculture Centre
Box 1030
Guelph, Ontario
N1H 6N1

Guiding principles governing the use of animals. These guiding principles have been prepared by the Canadian Council on Animal Care. They are recommended for use by departments of education and school boards across Canada so that adequate safeguards exist to ensure the proper care and use of animals in experimentation in the schools in their jurisdiction. These guidelines are not for use by students preparing projects for exhibit in science fairs. These students must adhere to the Youth Science Fair Regulations for Animal Experimentation.

Biological experimentation involving animals in the classroom is essential for an understanding of living processes. Such studies should lead to a respect for all living things. All aspects of such studies must be within the comprehension and capabilities of the students undertaking them.

Lower orders of life are preferable subjects for experimentation at the preuniversity level. Bacteria, fungi, protoza, and insects can reveal basic biological information; they should be used for experimentation wherever and whenever possible.

All students conducting projects involving vertebrate animals are expected to adhere to the following guidelines:

1. No experimental procedures shall be attempted on a vertebrate animal that would subject it to pain or discomfort, or interfere with its health.

2. Surgery shall not be performed on vertebrate animals, and anesthetic agents must not be used.

3. Dissections, although prescribed in certain science courses, shall be kept to a reasonable minimum. For instance, each group of students in a class could examine the several physiological systems of a single specimen. Special care must be given to specimen storage, particularly if the work on a specimen is spread over a period of several weeks. Students must wash their hands thoroughly with soap and water after handling specimens in a dissection investigation.

4. Experimental procedures shall not involve the use of:

   a) micro-organisms that can cause diseases in humans or animals;
   b) ionizing radiation;
   c) cancer-producing agents;
   d) chemicals at toxic levels;
   e) alcohol in any form;
   f) drugs that may produce pain;
   g) drugs known to produce adverse reactions or side effects or capable of producing birth deformities.

   The use of any drug on animals by an unqualified person is not permitted. This can only be done by veterinarians or persons authorized by a veterinarian.

5. Experimental treatments shall not include electric shock, exercise until exhaustion, or other distressing stimuli.

6. In training programs in behavioural studies only reward (positive reinforcement), not punishment, should be used.

7. Food shall be palatable and of sufficient quantity and balance to maintain a good standard of nutrition. Food containers must be clean. Animals shall not be allowed to go below the maintenance level of nutrition. Clean drinking water shall be available at all times. Containers for food and water must be designed specifically for that purpose.

8. If egg embryos are subjected to experimental manipulations, the embryos must be destroyed humanely two days prior to hatching. If normal egg embryos are to be hatched, humane arrangements must be made for the disposal of the young birds. Egg shells may contain campylobacter, salmonella, and other pathogenic bacteria. After handling eggs, students should wash their hands thoroughly.

9. All experiments shall be carried out under the supervision of a competent science teacher. It shall be the responsibility of the qualified science teacher to ensure that students have the necessary understanding for the study to be undertaken.

10. All experimental animals used in teaching programs must be properly cared for. Animals' quarters shall be made comfortable through provisions for sanitation, protection from the elements, and space for exercise. The living quarters shall have surfaces that may be easily cleaned, good ventilation and lighting, and well-regulated temperatures, and cages should be of sufficient size to prevent overcrowding. Students must not be allowed to take animals home to carry out experimental

studies. All studies involving animals must be carried out in a suitable area in the school. Animals must be protected from direct sunlight or other environmental factors that may disturb their well-being.

11. Colonies and animal quarters shall be supervised by a science teacher experienced in animal care. The students and other animal-care staff shall be trained and required to handle the animals gently and humanely.
12. The use of animals must comply with existing local, provincial, and federal legislation.
13. All animals must be disposed of in a humane manner. If euthanasia has to be carried out, an approved method must be used and carried out by an adult experienced in such techniques.
14. The procurement and use of animals and birds must comply with the Migratory Birds Convention Act of Canada and the Endangered Species Act of Canada, as well as any existing provincial legislation concerned with wild animals and exotic species.

Information on the care and housing of individual species is provided in *The Care of Experimental Animals: A Guide for Canada*, available from the Canadian Council on Animal Care. (The address is given below.)

Animal experimentation in science fairs. Biological experimentation is essential for an understanding of living processes. Such studies should lead to a respect for all living things. Capable students anxious to pursue a career in biological sciences must receive the necessary encouragement and direction. *All aspects of a project must be within the comprehension and capabilities of the student undertaking the study.*

Lower orders, such as bacteria, fungi, protozoa, and insects, can reveal much basic biological information. If experiments are to be conducted on living subjects for science fair projects, only lower orders of life are to be used.

Vertebrate animals are not to be used in experiments for projects for science fairs. However, the following activities are permissible:

- observations of the normal living patterns of wild animals in their natural environment or in zoological parks, gardens, or aquaria
- observations of the normal living patterns of pets, fish, or domestic animals. No living animal shall be displayed in exhibits in science fairs

Cells such as red blood cells, other tissue cells, plasma, or serum purchased or acquired from biological supply houses or research facilities may be used in science-fair projects. Observational studies on chick egg embryos may also be used in science-fair projects. If normal egg embryos are to be hatched, humane arrangements must be made for the disposal of the chicks. If such arrangements cannot be made, then the chicken embryos must be destroyed on the nineteenth day of incubation. No eggs capable of hatching may be exhibited in science fairs.

All experiments shall be carried out under the supervision of a competent science teacher. It shall be the responsibility of this teacher to ensure that students have the necessary understanding for the study to be undertaken.

Whenever possible, specifically qualified experts in the field shall be consulted. For information and the names of qualified experts, write to:

Canadian Council on Animal Care
151 Slater Street, Suite 1105
Ottawa, Ontario
K1P 5H3

Youth Science Foundation
Animal Care Committee
151 Slater Street, Suite 302
Ottawa, Ontario
K1P 5H3

Suggestions regarding experiments involving animals. The following examples of acceptable areas of animal experimentation at the preuniversity level are offered for the benefit of youth-science-fair participants, biology teachers, and science-fair directors.

1. *Physiology.* Students might measure the normal physiological parameters, such as respiratory rate, heart rate, temperature, quantity of food eaten, and the length of time dye-makers take to pass through the gastrointestinal tract and appear in the feces.
2. *Reproductive biology.* This may be studied with mice, hamsters, gerbils, or rats. The species may be observed under a variety of conditions. Studies may be repeated on the same animals because of the short gestation period. The animals may be treated in the following ways or modifications of these ways:
    a) Before breeding, a group of animals is gently handled and given kind treatment by the student each day. After breeding, the gentle handling continues. Students handling the animals during or after breeding should wash their

hands thoroughly with soap and water. (Animals harbour many zoonotic diseases such as salmonella and campylobacter, and leptospira and toxoplasma infectious cysts may be present in the faeces or urine of rodents.)

b) A second group of animals does not receive this gentle treatment but is left to breed in the cages.

c) Two groups of animals are placed in a darkened room and not allowed any light; one group is removed each day and handled, and the other group is not.

Many variations of this kind may be carried out without causing any distress to animals. The number of young born is observed and recorded. In the same way, the number of young that are weaned is observed. In addition, the habitats of the animals can be studied in terms of such factors as the provision of proper bedding materials or nest boxes.

3. *Maze studies.* Students may wish to discover factors that lengthen or shorten the time it takes for an animal to journey through a maze. They might examine, for example, differences caused by variations in the amount of gentle handling the animal receives or in the environment in which the animal lives (e.g., the animal might be kept in darkness or light, be provided with soft music or rock music, kept cool at 18°C or warm at 28°C). Only positive reinforcement should be used; negative influences such as electric shock, food deprivation, drastic temperature extremes, or painful prodding must not be permitted. With respect to temperature, variations within 3°C below to 6°C above the recommended normal maintenance temperature for the animal should not be exceeded. For example, if the normal temperature for a rat is considered to be 22°C, it is not recommended that the effects of temperature below 19°C or above 28°C be studied.

4. *Environmental studies.* Again, light, darkness, and temperature may be considered in relation to gains in mass, food intake, or urinary output in young animals. The animals can be maintained in the darkness and handled or not handled, and then be brought into the light and handled regularly. Temperature variations should not exceed those mentioned under "Maze studies" above. Increase or decrease in mass can be observed under each variable.

5. *Nutritional studies.* Again, none of these studies should involve the production of deficiencies or disease in animals. However, many studies can be carried out in which animals eat a balanced diet in different forms: for example, one group may be given food in a cube state, another group may be fed on a powdered ration or a meal mixture, and a third group may be given food that is moistened with water. The animals used should be in the growing stage. They should be weighed each day, and such measurements as gains in body mass recorded. In this way, students learn to handle the animals and to make reliable measurements. In such studies, fecal and urinary output are other possible variables that can be measured. Students must wash their hands thoroughly after touching the animals or their urine or faeces.

6. *Behavioural studies.* The effect of enriched environments (as compared with environments in which only the necessities, such as food and water, are provided) on the behaviour of animals may be studied. Students may let their imaginations free to create these environments, which might feature bright or dull colours, round or square objects, and so on. Many psychology departments conduct studies in which behavioural scientists look at the effects of enriching an environment. This has a positive application to contemporary problems of human sociology.

7. *Anatomical preparations.* The bodies of dead animals may be obtained from humane societies or research laboratories where animals have been killed humanely. A freshly killed (euthanized) animal should not be used in the classroom because it may have been killed during the incubation period of an illness-causing agent. Many animals in the care of the Humane Society are stray animals for which the rabies-vaccination status may be unknown. After handling a dead carcass, students are to wash their hands thoroughly. The preparation of skeletons from these animals by cleaning the bones and restructuring the body is a giant task. A comparison of the various bones in animals is another interesting study, particularly if the function of the bones is also considered.

8. *Genetics.* Mice, rats, hamsters, or rabbits of various colours may be bred, and the colour adaptations recorded. Similarly, the effects of random breeding, brother and sister matings, and line breeding might be studied with respect to the number of young born, their colours, their sex, and so on.

9. *Field studies.* Data can be collected concerning the numbers of wild animals within a given area (e.g., the woodpecker population in an area close to an industrialized or built-up area and one far removed). There are many studies that can be developed to determine the effects on animals of the various combinations of changes in the environment that humans have produced. Students can also build feeding stations and study bird populations or animal populations as they arise. An observation of animals in a dump is a worthwhile project.

10. *Study of the senses.* In studies based on sight, smell, and taste, only those things with which we may daily come into contact should be considered. Various studies can be done in which the behaviour of animals can be observed when they are exposed to various colours in their environment or to such strong odours as peppermint or onion. Ordinary food stuffs that are fed to laboratory animals can be coloured with vegetable dyes or altered with respect to taste by the addition of spices. Nothing should be added to the food that would be regarded as unacceptable to human senses.

9.4 The Safe Use of Plants

When flowers and bread mould are handled, care should be taken that pollen or spores, to which some students may be allergic, are not excessively distributed throughout the classroom. As well, some plants in gardens, fields, forests, or the home may be poisonous, even though they are beautiful. Such plants may cause stomach and intestinal irritation, poisoning of the system, mouth and throat-lining irritation, and skin and eye irritation. The seriousness of plant poisoning will usually depend on the amount of the plant swallowed. With some plants, even a small amount can be dangerous. A listing of some common toxic plants and their effects is found in Appendix D; this list is not a comprehensive one, however.

Students should be clearly instructed about poisonous and wild plants. They should:

a) learn about the plants in the community that could cause harm;
b) learn to recognize the most common poisonous plants, such as poison ivy;
c) wash their hands after handling plants, seeds, bulbs, fruit, and similar items;
d) keep plant seeds, bulbs, and fruit well away from small children who are not under close adult supervision.

Students should *not*:

a) eat wild plants, including mushrooms;
b) eat any unknown plant nor suck plant nectar;
c) eat seeds, bulbs, or fruit;
d) play with plants or handle them excessively;
e) brew home-made medicines from plants.

If a student chews on or swallows part of a plant that is suspected of being poisonous, he/she should be induced to vomit. Medical help should be sought immediately. Even simple skin irritation may require medical attention. A sample of the suspected plant may aid in the determination of needed treatment. Students should be advised that it is wise to leave plants alone in their natural state.

Section 10

Values in Science Education

10.1 The Role of Values Issues in Science Courses

A major purpose of education is to help students become effective citizens who can comprehend and weigh intelligently issues that confront society. Science education has an important role to play in the attainment of this goal, because many of today's most difficult societal issues relate to the use of science to modify basic conditions of life and to shape the future. Examples of such issues are the use of computer surgery, interferon, cloning, and genetic engineering. Articles on such topics are of interest to students because of the significance of the issues they raise.

By focusing on science-related issues, science education can help students to learn decision-making skills, to develop values, and, if appropriate, to reserve judgement for a future time, all of which will contribute to their effectiveness as citizens. Studying issues in the science classroom provides students with opportunities to think clearly and logically and to deliberate in an honest and open manner. Further, because issues often contain important moral components, students have opportunities to consider the ethical implications of various points of view in the light of fundamental societal values such as compassion, co-operation, courage, courtesy, freedom, generosity, honesty, justice, loyalty, moderation, patience, peace, respect for the environment, respect for life, respect for others, respect for self, responsibility, self-discipline, sensitivity, and tolerance. See Ontario, Ministry of Education, *Personal and Societal Values*, Curriculum Ideas for Teachers (Toronto: Ministry of Education, Ontario, 1983).

Issue-focused science education is personal or relevant science, in which students feel more than a passing interest in the investigative process and in its potential solutions. However, using issues as organizers for the science curriculum requires special care. An adequate study of a science-related issue includes the examination of three elements: scientific knowledge, its application as technology, and the resulting societal implications. Table 6 shows two examples that illustrate the combining of these three elements in relation to an issue from each of the physical and biological sciences.

Table 6: Science-Technology-Society Issues

Issue	Science	Technology	Society
Should society commit itself to using nuclear power to generate electricity?	Nuclear processes: atomic structure, fission, radioactivity, conservation of energy	Nuclear technology: extraction, fuel supply, reactor design, fail-safe mechanisms	Societal implications: cost efficiency, health hazards, risks, alternative sources of energy
Should genetic engineering be supported or opposed?	Heredity concepts: DNA and RNA, transcription, mutation	Genetic engineering: recombinant DNA, splicing, cloning	Societal implications: future benefits, combatting disease, genetic warfare, employment issues

Traditionally, science education has usually addressed only the first of these elements, scientific knowledge. However, the other two elements are equally important when issues are being examined. For example, in studying the issue of whether or not society should commit itself to using nuclear power to generate electricity, more is involved than learning scientific knowledge about combustion, water flow, and nuclear fission. Students must have the opportunity, for example, to examine technological applications of scientific knowledge by learning about reactor requirements and related safety design. In addition, students must be involved in the study of the societal implications of using the technology, including an analysis of possible risks.

Science then is a subject that involves issues, morals, and even beliefs. Although many beliefs, particularly religious ones, cannot be tested with test tubes and Bunsen burners, they often relate very closely to science. Issues in science should not be avoided solely because they are issues. They should be included in science education in order to raise student awareness and to search for solutions. The thirteenth goal of education (see section 2) states that a purpose of education is to help each student to "develop values related to personal, ethical, or religious beliefs and to the common welfare of society. Moral development in the school depends in part on a consideration of ethical principles and religious beliefs, a respect for the ideals held by others, and the identification of personal and societal values."

Issues result from differences of opinion about what is true or what should be done. Issues often involve ethical components, which must be taken into account. Some examples of science-related issues follow.

Topic	Issue
Population growth	If the rate of population growth is not controlled, what problems are likely to arise? If control is necessary, what means should be adopted?
Energy resources	To what extent, if any, are non-renewable resources being depleted? How should conservation, if needed, be accomplished? What other viable alternatives exist?
Food resources and famine	What ethics, if any, govern the present distribution of available food supplies? What can or should be done in the immediate and long-range future?
Pollution	What kind of problems exist in regards to pollution? How should waste management be handled?
Nuclear disaster	What would be the probable outcomes of a nuclear disaster? What can be done to prevent a nuclear disaster?
Sexuality	How far should a science program in schools delve into the concept of human sexuality? To what extent should topics such as birth control, teenage pregnancies, sexually transmitted diseases, and the act of human reproduction be part of a teenager's science education?
Nuclear-generated electric power	To what extent is nuclear technology economical, practicable, and safe? Are viable alternatives available? Should we be building nuclear power plants? Why, or why not?

Topic	**Issue**
Landfills	What are the potential long-term effects on the surrounding ecosystem of landfill sites? Who should decide where a landfill site should be located and what should be allowed to be dumped there?
Pesticides	What is the impact on the soil, animal and plant life, and people in areas where pesticides are produced and used? To what extent should their use be regulated?
Origins of life	How valid is the theory of biological evolution? What other explanations are there for the origin of life? What scientific issues are raised regarding the origin of the universe and life? How admissible is the scientific evidence that is used to support various perspectives on origins?
Life and death	When does a person's biological life start? When does death occur? How are life and death defined? Should they be redefined? Should the use of life-support systems be optional?
Drug abuse	What criteria are used to determine whether substances like alcohol and tobacco are drugs? How should society determine whether certain drugs that are currently illegal should remain so or be legalized? Should substances like alcohol and tobacco be made illegal or not?

10.2 Handling Sensitive Issues

Issues by definition involve differences of opinion, which sometimes involve deeply held viewpoints and beliefs, religious and otherwise. The following principles are to be observed when sensitive issues are dealt with in the science curriculum:

1. School boards are to ensure that instruction related to sensitive issues in science is treated in a sensitive and scientific manner. Care should be taken to introduce such issues only at times when the maturity level of students is appropriate. The premature treatment of an issue must be avoided.

2. When dealing with any theory in the classroom, the teacher is expected to discuss the strengths, limitations, and tentative nature of the theory with students. Students should be given ample opportunity to consider the processes and the data gathering on which such a theory depends. When examining the validity or acceptability of a theory, the teacher is to stress the importance of the theory as an explanatory device that is intended to correlate with observed phenomena.

3. It is not the intention of the Ministry of Education explicitly to include or exclude all viewpoints or explanations of any given phenomenon or process mentioned in the science curriculum. Generally, the most widely accepted viewpoint is required in the program, but this must not be interpreted as implying that other perspectives are not valid or are not to be presented or discussed. In fact, the introduction of two opposing views often heightens the interest of students and results in a more open-ended and discerning approach to an issue-oriented topic.

4. The science staff within a school, in consultation with the principal, should decide which issues of relevance and concern to students and society will be emphasized. Community concerns related to such issues must be taken into consideration in the design of specific courses. There should be a sound rationale for deliberately including a sensitive issue in the program.

5. Some issues will be introduced through curriculum design; others, through the spontaneous initiative or curiosity of a student. In either case, the teacher shall ensure a sensitive and rational treatment of the issue and act as a role model in an environment of mutual respect. The teacher should assist students to:

   a) develop, articulate, and reflect on their own points of view;
   b) listen to and consider the views of others;
   c) try to understand and appreciate both sides of an argument;
   d) take into account relevant information;
   e) consider various interpretations of collected data or observed phenomena;
   f) appreciate the possible ethical, cultural, racial, national, or religious implications of a point of view;
   g) grow intellectually.

6. The background information that is provided about any sensitive issue should:

   a) represent various scientific points of view in a way that minimizes prejudice;
   b) reflect students' interests, needs, capabilities, and level of maturity;
   c) reflect community concerns as well as provincial, national, and international implications;
   d) reflect complementary or divergent perspectives that may be held by people with different cultural, racial, national, or religious backgrounds;
   e) relate to Ministry of Education curriculum-guideline requirements.

7. In science classes different viewpoints, including those based on deeply held religious or cultural beliefs, should be presented and discussed in a respectful and intelligent manner. If an issue in the science curriculum relates to religious perspectives, the teacher and students must understand that in the science classroom other realms of knowledge, such as religion with its doctrines and faith orientation, must be respected for their own intrinsic value and contributions. However, just as religious education by its nature must involve students in the study of religious knowledge and methodology, science education must involve students in the study of scientific knowledge and methodology. Students of all backgrounds should be encouraged to view science education as an opportunity to learn about the scientific viewpoint. If the material being studied in a particular unit is likely to be incompatible with the deeply held religious beliefs of some students and their parents, then such material should be treated sensitively and with discretion. In some situations it may be appropriate to assign alternative material to the students concerned.

8. When evaluating student achievement in a topic that is sensitive or controversial, the teacher must take care to observe the following guidelines:

    a) Students may be asked to outline or describe a scientific theory or view even though they may not believe in it. They should be informed that their answers will not imply their *belief* but serve as an indication of their *knowledge*.
    b) If students are asked to outline or describe their beliefs or opinions about an issue, then the evaluation must be based on purely objective features such as organization, reasoning, sequence, development, readability, and overall presentation, not on the actual belief or opinion, particularly if it is divergent from that of the teacher.
    c) Students are to be informed in advance of a test or examination of the criteria that will be used in the evaluation process, particularly when a question deals with a sensitive or controversial issue.

D. Implementation

Sections

11. Curriculum Planning and Staff Development
12. Resources
13. Modes of Delivery
14. Evaluation

Section 11

Curriculum Planning and Staff Development

This section deals with the responsibility for implementing the science program described in this guideline for the Intermediate and Senior Divisions. Since program delivery is an ongoing task of school boards and their schools, many details must remain in the hands of local administrators and teachers. The first parts of this section are presented in the form of a checklist of questions, which will enable educators to ensure that they have not missed any steps in the implementation process. While the checklist alone will not bring about a change in the curriculum, it can help to organize the steps to be taken during implementation to ensure that alterations are made to existing practices, learning materials, and teaching approaches and attitudes. The last two subsections, on school-board curriculum documents and staff development, are set out in a descriptive way, although the points included may also be used as a checklist by implementers of the science guideline.

11.1 Policy Planning at the Board Level

The following are items for which the school board should have clear policies.

1. Timetable for Introducing Changes

a) When will administrators and principals be informed of the new science program? ☐

b) When will the new Grade 7 and 8 science courses be in place? ☐

c) When will the new Grade 9 and 10 science courses at all appropriate levels be implemented? ☐

d) When will the Grade 11 and 12 courses be fully implemented? ☐

e) When will the science OACs be in place? ☐

2. Administrative Considerations

a) What plans, time allocations, and assistance are available to prepare teachers to make the switch to the new courses? (See also subsection 11.2, point 1.) ☐

b) What textbooks or other learning materials will be available for teacher and student use? ☐

c) What needs to be done to ensure that laboratory facilities are functional and effective for the delivery of the program? ☐

d) What science equipment will be needed, particularly for mandatory student activities, and when and how will equipment that is not on hand be procured? ☐

e) What is the school board's plan regarding the use of computers in the science program? ☐

f) What is the school board's safety policy in regard to science? Is the implementation of the safety policy effective? ☐

g) Have teachers established a mechanism to alert administrators to sensitive and controversial issues that arise in science? ☐

h) Is there a school-board plan for monitoring the implementation process for the new science program from Grade 7 on? ☐

i) Will a supervisory officer, a science co-ordinator/consultant, or a designate be the primary person responsible for providing leadership in the science-program implementation process for the school board? ☐

3. Co-ordination of Board-wide Curriculum Policy

a) How will all schools deliberately ensure that attention is given to incorporating the goals of education (section 2) and the aims of the science curriculum (section 3) in the science continuum in the Intermediate and Senior Divisions? ☐

b) How will all guidance departments and counsellors become familiar with the broad policies and programs in the science guideline in order that the best advice may be given to students? ☐

c) How will schools ensure that the language-across-the-curriculum policy is reflected in the science program? ☐

d) How will a proper balance between content and process (subsection 5.1) be assured? ☐

e) How will adherence to the teaching policy set forth in subsection 5.3 be checked? ☐
f) How will the time allocations for each unit be controlled within a reasonable margin of variation? ☐
g) Will outlines of locally designed units be filed in local school offices or the board office? ☐
h) How will the curriculum emphases mentioned in subsection 3.4 be incorporated into the science program? ☐
i) Will the board make provision for locally designed curriculum resource guides that will help teachers interpret and implement the science guideline in an effective manner (subsection 11.4)? ☐
j) What use can be made of ONTERIS in local curriculum development? ☐
k) How will the board provide science equipment for Grade 7 and 8 classes in schools where the equipment is not presently available? Can it adopt a kit-sharing program? ☐
l) What overall provisions will be made in science:

- to meet the needs of exceptional students (subsection 6.2)? ☐
- to take into consideration individualized instruction and life-management skills where appropriate (subsections 6.3 and 6.4)? ☐
- to ensure that all courses include some treatment of employment awareness (subsection 6.5)? ☐
- to alert all teachers, not only science teachers, to support strongly a policy of sex equity in terms of the participation of girls and boys in science and related subjects, such as mathematics, computer studies, and technological studies (subsection 6.6)? ☐
- to develop strong ties between science teachers and the teacher-librarian(s)? ☐

4. Various Modes of Delivery

a) In what ways can each of the following, where appropriate, meet the needs of those taking science courses: co-operative education, transition courses, school-related and community-related packages, bilevel or multigrade classes, summer school, night school, correspondence education, adult education? ☐
b) Who has been appointed to be responsible for each of these areas? ☐
c) What mechanisms ensure their implementation? ☐

5. Evaluation of Program Effectiveness

(See also subsection 14.4.)

a) How can the effectiveness of the science program be evaluated? ☐
b) When should this be done, how often, and by whom? ☐
c) How can improvements be implemented? ☐
d) How can continual staff development be established? ☐

11.2 Program Planning at the School Level

The following are items for which the principal, in consultation with the head of the science department or a designated teacher, should enunciate expectations or develop plans.

1. Staff Preparation for New Courses

a) How will the school determine which science courses should be offered? ☐
b) How are teachers to be prepared to introduce changes in order to implement the guideline? ☐
c) What follow-up techniques will be used, when, and by whom? ☐
d) Is there an organized mentor system to assist a new science teacher or one who is a crossover teacher to science from another subject area? ☐
e) What strategies can be adopted to enable the science teacher and the teacher-librarian to plan resource-based units and to see that necessary resources are available for student use? ☐

2. Course Outlines

(See also subsection 11.4.)

Note: The terms *course outlines* and *courses of study* are described in section 11.4 so that their meanings will be consistent for purposes of this guideline.

a) Who will be responsible for preparing course outlines? ☐
b) What components should they contain? (See subsection 4.8 of OSIS, as well as subsection 11.4 of this document.) ☐
c) What steps will be taken to share the course outlines in science with parents who may wish to examine them? ☐

3. Textbooks and Resource Materials

(See also subsection 12.3.)

a) What is the board's and school's policy regarding availability of science textbooks for each student, particularly in regard to their being taken home for use in homework assignments and study? ☐
b) What budget is allotted for other science-related resource materials? ☐

4. Communication With Students and Parents

a) What provision is there to ensure that all students (and their parents or guardians) know what science courses are available, the preferred routes towards Senior science courses, and the prerequisites for the science OACs? ☐
b) How is student progress in science to be conveyed to parents and how often is this to be done? ☐
c) How are parents to become informed of sensitive or controversial issues in the science program so that clear communication can exist between the school and parents before, rather than after, the fact? ☐
d) What strategies can be implemented to help parents adopt a positive attitude towards sex equity in regard to the science courses that may be selected by their sons and daughters? ☐

5. Evaluation of Student Achievement

(See also subsection 14.2.)

a) How often and when are tests and formal examinations to be held in the science program and how will students be advised of the schedule well in advance? ☐
b) How can an adequate variety of different types of evaluation questions (e.g., restricted-response items, extended-response items) be ensured so that student achievement is assessed over a wide range of abilities (e.g., problem solving, laboratory skills)? ☐
c) What procedures can be adopted to ensure that all objectives identified in this guideline – attitudinal, skill, and knowledge – will be evaluated? ☐

11.3 Course Planning at the Teacher Level

The following features must be considered when teachers plan and design new or revised science courses within a school.

1. Communication With Neighbouring Schools

a) If equipment is to be shared among schools, in what order should each school teach the units of the course? Should principals, heads of science, or a teacher negotiate this sequencing of units? ☐
b) How can professional-activity days for curriculum planning in science be used to the greatest advantage for neighbouring or feeder schools? ☐
c) How can a family of schools arrange for meetings of science teachers to discuss curriculum matters, the sharing of equipment, and the disposal of hazardous wastes? ☐

2. Communication With Other Teachers

a) When will science teachers discuss related curriculum topics with teachers of subjects such as mathematics, computer studies, technological studies, family studies, physical and health education, geography, and English? ☐
b) How will science teachers relate to guidance teachers and counsellors? ☐
c) How will the science courses be enhanced by the use of the school's library resource centre? (See also subsection 12.2.) ☐

3. Design of Science Courses

a) In what order will core units be taught? ☐
b) What optional units will be included? ☐
c) How will the achievement of the objectives of a course be monitored? ☐
d) What kind of emphasis will be adopted at different stages in a course so that the aims of the science curriculum are integrated into the program? (See subsection 3.4.) ☐
e) How will all points in the teaching policy (see subsection 5.3) be observed throughout the course? ☐

f) How will language development (see section 7) be an integral part of the instruction? ☐
g) In which topics will SI metric units be used? (See subsection 8.2.) ☐
h) How will sufficient attention be given to the issue of safety? (See section 9.) ☐
i) How will sex equity be ensured? (See subsection 6.6.) ☐
j) How will the needs of exceptional students be met? (See subsection 6.2.) ☐
k) How are animals and plants to be cared for in the science rooms? (See subsections 9.3 and 9.4.) ☐
l) How will time allocations for the units within a course be monitored? ☐
m) How will the evaluation of student achievement be carried out? (See subsection 14.2.) ☐
n) How will modes of delivery such as bilevel classes, co-operative education, and transition courses be handled? (See subsections 13.1 and 13.2.) ☐
o) How will computers be used to assist in the instruction? (See subsection 12.5.) ☐
p) How will sensitive or controversial issues in a course be identified, treated, and communicated to administrators and parents? (See subsection 10.2.) ☐
q) How will career awareness become an integral part of each course? (See subsection 6.5.) ☐
r) In what ways can the needs of adult students be met? (See subsection 13.4). ☐
s) To what extent will the achievements of scientists, including Canadians, be emphasized? ☐

4. Teacher Professional Development

(See subsection 11.5.)

a) How will science teachers be able to make their professional needs known to the administration? ☐
b) How will such needs be analysed and given adequate attention? ☐
c) In what ways can science teachers tap resources for professional development from science teachers' professional organizations, teachers' federations, universities, colleges, and industry? ☐

11.4 School-Board Curriculum Documents

When a curriculum guideline is released by the Ministry of Education to the school boards, locally developed documents are often prepared to provide further direction for local implementation of the guideline. Included among such documents are curriculum resource guides, courses of study, and course outlines.

The curriculum resource guide. This document, sometimes called a *second-generation document*, or *users' guide*, is usually generated by a committee for the school board and is prepared for board-wide use to promote consistency in guideline implementation and interaction among teachers. It is not required under a regulation or under OSIS. It should assist teachers in their design of local courses and permit beneficial adaptations to suit the needs of individual classes in each school.

In the science program such a resource guide, developed within the framework of this curriculum guideline, might include such components as the following:

a) the school board's policy regarding the implementation schedule for new courses;
b) the board's policy in such areas as language development, sex equity, sensitive issues, safety, transition courses, and formal examinations;
c) the suggested organization of the units of study that make up the course(s), with an indication of the flexibility that is permitted at the local school level;
d) the overall curriculum emphasis or emphases that may be adopted for sets of units of study in order to combine content with the aims of the science curriculum (see subsection 3.4);
e) a suggested sequence of lesson plans for each unit, including learning objectives, teaching strategies, and resource materials;
f) the student activities that are to be performed, with some indication of the equipment needed, any special techniques or strategies that might be adopted, and areas where safety precautions must be established;
g) applications, societal implications, and career awareness that should be included in each unit of study;
h) special features that apply to exceptional students;
i) policy regarding the use of calculators and computers;
j) strategies for evaluating student achievement;
k) ways by which the delivery of the science program might be evaluated;
l) ideas for the professional development of science teachers;
m) suggestions on ways in which science courses might be adapted to adult learners.

School boards are encouraged to submit their curriculum resource documents for inclusion in the data base in ONTERIS (Ontario Educational Research Information Service). Supervisory personnel, principals, and teachers will find it useful to access ONTERIS to identify sources of support materials. The data-base entries include research studies, curriculum-development articles, and school-board curriculum resource documents, which will provide additional assistance to teachers and school-board teams that are preparing local curriculum documents. ONTERIS may be accessed via a terminal or a microcomputer. Further information about ONTERIS may be obtained from:

Co-ordinator, Information Resources
Computers in Education Centre
Ministry of Education
Mowat Block, 13th Floor
Queen's Park
Toronto, Ontario
M7A 1L2

The course of study. This should be a personal document showing how a teacher plans to implement his/her course with the particular students or classes for which he/she is responsible. Such a document may be common to a number of teachers or schools within a board. Courses of study are referred to in the Education Act (section 8, subsections 1b and 1c). The curriculum guideline is to be the basis for any course of study that is developed.

As a teaching plan the course of study should provide enough detail to indicate the design of a particular course, including its objectives, subject matter, development of scientific processes, timing and sequencing, teaching strategies, and other features. The school board's curriculum resource guide should be of great assistance in helping teachers to develop their own courses of study.

The course outline. This document is referred to in Regulation 262 and in OSIS. It is assumed that "outline" indicates a summary or brief overview of a course and need not contain all of the points that may be included in a teacher's personal, detailed course of study. However, since the course outline is to provide useful information for students' parents, it must, as indicated below, include certain components. Up-to-date copies of all course outlines should be on file in the school so that parents can examine them. (Subsection 4.8 of OSIS states: "It is ... important that parents be informed of the school's course offerings and their content. Since students under the age of eighteen require parental approval for decisions on course choice, information regarding course content must be made available at the school.")

According to OSIS, such an outline must include the following information:

a) the name of the Ministry of Education guideline on which the course is based
b) the level of difficulty at which the course is offered
c) the credit value of the course
d) the core content of the course in the sequence in which it will be studied
e) the evaluation practices that will be used
f) the name(s) of the textbook(s) to be used as well as any other learning materials that are essential to the course

All of these components except (b) and (c) apply to course outlines for the Grade 7 and 8 science courses.

In addition to the above, it is recommended that a course outline for a science course also include the following:

a) the general aims and/or objectives of the course
b) an indication of the students for whom the course is intended, with some reference to any preferred preparation or prerequisite needed for entry into the course
c) some indication of the criteria to be used in evaluating student achievement and a breakdown of the overall evaluation weighting to be used
d) reference to teaching strategies that may be of particular interest to students' parents
e) general expectations in addition to the mastery of science that may provide useful information to students' parents (e.g., language policy; safety policy, including behaviour expected of students; and policy related to sensitive issues)

11.5 Staff Development

Since teachers of science are to design and implement courses within the framework of this guideline, it is essential that they have an overview of the tasks to be accomplished. Their work will involve:

a) becoming familiar with changes that have been made in existing courses and with the descriptions of new courses;
b) preparing courses of study and course outlines;
c) deciding on the best pedagogical approaches to use in order to blend subject matter with curricular emphases to ensure that the aims of the science program are achieved;
d) mastering subject matter and scientific processes involved in the courses to be taught so that their content and methodology is up to date and relevant;
e) being conversant with policies and practices that relate to such areas as time allocations, exceptional students, life-management skills, employment awareness, language development in science, values education, safety, computers, and evaluation techniques;

f) selecting appropriate equipment and supplies;
g) selecting and working with the principal and teacher-librarian to obtain the most appropriate textbooks and other learning materials;
h) reviewing the program on a continuous basis to seek ways to improve the delivery of the science program.

Among the many challenges that science teachers face is the need to keep informed about modern scientific developments and to maintain competence in the science disciplines in which they are involved. This is especially important in relation to four areas. First, teachers must become familiar with scientific advances and technological changes, such as those in the areas of genetics, robotics, information technology, medicine, environmental controls, energy resources, industrial processes, and biotechnology. Second, teachers are expected to be aware of examples of the applications and societal implications of science and technology, including Canadian achievements in science, and to weave these into their courses in order to relate science to the world of their students. Third, teachers must understand the implications of new information technology, the ways in which microcomputers can be effectively used in science courses, and the impact and influence of computers in general on science education. Finally, teachers must constantly keep up to date on laboratory safety and not be content simply to follow practices that were accepted five or ten years ago.

The responsibility to meet the challenge of change while simultaneously maintaining a hold on valued and proven practices requires professional expertise and dedication on the part of teachers. It also requires that they be given adequate time for professional development. Ongoing staff development must be given a high priority and must be established as an essential component of school-board planning and co-ordination. In-service programs should focus on key issues that affect the implementation of the new science program, such as the four areas outlined above.

The active support of the school board can do much to encourage responsible teachers to avail themselves of professional-development opportunities, such as updating courses and science-education conferences. Staff-development programs should, if at all possible, provide teachers with training with their peers, follow-up coaching, opportunities to attend courses and seminars administered by educational institutions, adequate resources, and time for self-directed learning.

Staff-development programs are also required to help teachers meet the needs of exceptional students who are integrated into regular science programs. For such students the course content, scientific processes, safety precautions, and related teaching strategies will require modification or special attention. Teachers need advice and suggestions on appropriate strategies so that exceptional students can receive the best education possible.

A co-operative and co-ordinated program that involves constituencies such as school boards, faculties of education, colleges of applied arts and technology, science and engineering faculties of universities, business and industry, the Ministry of Education, science-teacher associations, and the Ontario Teachers' Federation is needed to assist science teachers to acquire the updating and professional development they require. Time must also be made available so that teachers can actively participate in opportunities for retraining.

Where crossover teachers, that is, those who do not normally teach science, are involved in the science program, special care must be taken in regards to safety. Teachers who have had little or no experience in science education must be thoroughly familiarized with all of the safety requirements of a laboratory and with the student activities that are to be completed. Faculties of education, professional organizations, science-teachers' associations, school boards, and teacher colleagues should provide them with support material and assistance with subject matter so that the quality of the science program will not be compromised. This assistance might take the form of detailed courses of study, lists of appropriate and available resources, copies of exemplary student assignments and tests with marking schemes, and clear instructions about accident prevention. School boards should encourage crossover teachers to take summer courses or preparatory training *prior to* actually teaching science in the laboratory. They will also need ample opportunities to interact with other science teachers. The principal, through the head of the science department, the science co-ordinator/consultant or designate, or an experienced science teacher who can act as a coach, should play a major role in ensuring that such teachers have the expertise and resources to deliver effectively the science program assigned to them.

One technique that has proved effective in providing professional development, particularly in the implementation of a new program, is the use of coaching or interaction between two teachers. This technique can be beneficial, not only to inexperienced or crossover teachers, but to experienced teachers as well. Freedom must be given to teachers to exchange ideas and suggestions, to observe one another in the classroom where feasible, to help and be helped, and to give and receive constructive criticism. It is suggested that principals encourage this form of mutual assistance.

Section 12

Resources

The provision of resources such as learning materials and laboratory equipment for the teaching of the science program is the responsibility of the school board. Because these items play an essential role in the implementation of science courses, a major effort must be made to ensure that essential resources are available.

12.1 Science Laboratories and Equipment

All of the courses described in this guideline include science activities that students must do themselves. It is not satisfactory for students merely to watch demonstrations. If they are to experience the processes of science as a vital part of their education, they must personally do a great number of the investigations.

Science courses in the Intermediate and Senior Divisions require science laboratories. Where laboratories are not provided, science often becomes a teacher-dominated, lecture-type, bookish course, which does a great disservice to students.

If laboratories cannot be provided, everything must be done to try to accommodate students' experiences in the subject. This includes the provision of sufficient running water, heating devices, electrical outlets, disposal areas, and adequate storage space for essential equipment, including microscopes and balances. All desks should have horizontal surfaces, since sloping surfaces present a serious hazard. There should also be appropriate areas for aquaria, terraria, and other displays.

Science laboratories should be well designed and not too crowded. Attention to safety must also remain a high priority. Primarily, laboratories must be places where classes of students can carry out large numbers of scientific activities conveniently and safely in order to maximize their science education. The overcrowding of science laboratories is a serious concern in this regard. Students are often carefree and inexperienced. They are not always aware of the potential dangers of hazardous chemicals, electrical circuits, bacteria and viruses in cultures, radiation equipment, or Bunsen burner flames, to name only a few problem areas. In the interests of student safety, administrators and principals should do all that is reasonable to keep enrolments in science classes down to a manageable size and to ensure that the floor area per student provides adequate room to conduct experiments safely. (See also subsection 9.1.)

Some school boards may wish to consider the sharing of expensive equipment in order to reduce costs, particularly in a time of financial restraint. Schools must be responsible for following a plan for the systematic maintenance and replacement of equipment. All storage areas should be designed and maintained with due regard for the upkeep of the equipment and the safety of students, teachers, and the premises. The disposal of hazardous wastes must be carried out in conformity with government regulations.

12.2 Library Resource Centres

Learners in science courses should gain satisfaction from the dynamics of learning and be encouraged to become self-motivated, self-directed problem-solvers, who are aware of both the processes and uses of learning and derive a sense of self-worth and confidence from a variety of accomplishments. They should not be restricted to the laboratory for all of their science learning. For this reason science teachers will find the ministry's resource document *Partners in Action: The Library Resource Centre in the School Curriculum* (1982) well worth reading. The booklet focuses on the principal, the subject teacher, and the teacher-librarian and attempts to show "how their partnership in a school can lead to the creation of resource-based programs that promote learning through active inquiry, the mastery of learning skills, the development of language proficiency, and the appreciation of media" (*Partners in Action*, p. 4).

Resource-based learning provides a holistic approach to teaching and learning, in which laboratory activity is complemented by library involvement. Its goal is to provide a variety of learning experiences through a wide range of resources to satisfy specific curriculum objectives. Central to learning processes such as thinking, debating, reading, taking notes, graphing, presenting, and computing are resources such as textbooks (in addition to the one prescribed for a course), reference books, information files, magazines, films, audio and video recordings, filmstrips, microfilm, charts, diagrams, collections and displays of specialized materials, data bases, computer software, networks of out-of-school resources, photographs, and resource people.

The school library resource centre can support resource-based learning in the science program through the:

a) provision of resources, such as those listed above;
b) teaching of information skills, for example, how to access sources of information on particular topics; use reference books; gather and organize information; write a report; prepare an oral presentation; or annotate and summarize scientific writings;
c) creation of a learning environment that includes, for example, learning stations to support particular topics; library displays of student work; special displays of posters and pamphlets to illustrate the applications and societal implications of scientific phenomena; and promotion areas to advertise science centres, museums, science events, and local research activities or places to visit.

In this way the school's library resource centre can enhance science courses by:

a) providing opportunities for creativity and independent learning in science;
b) providing for individual differences in rate and style of learning;
c) familiarizing students with modern information technology, which can be used as a learning tool;
d) helping to maximize experiences for all students of science, especially exceptional students;
e) facilitating the enrichment of science courses, particularly through the provision of materials on scientific applications and societal implications.

Students should become familiar with special science-related features of a library resource centre, such as its science books and their associated Dewey-decimal ranges of numbers, science periodicals, reference handbooks, films, and software.

The science teacher should work in co-operation with the teacher-librarian to:

a) design learning experiences for students that will ensure the integration of the laboratory work with the resource materials in the library resource centre;
b) involve students in the use of both print and non-print materials;
c) make provision for appropriate activities in the library resource centre for exceptional students, including resource-based remediation and enrichment;
d) illustrate lessons with learning materials from the library resource centre and thus inform students of their availability;
e) select science-related resource materials for possible purchase;
f) work out details that relate to resource needs, requirements and deadlines for science assignments, the retrieval of information, the use of audio-visual equipment, and the general use of the library resource centre to facilitate good curriculum implementation in the classroom.

As outlined in *Partners in Action*, the teacher-librarian has a special role to play. This includes:

a) participating on the curriculum team by assisting science teachers in planning for the use of learning resources;
b) producing or arranging for the production of a wide variety of learning materials;
c) helping science teachers to implement the curriculum, for example, by demonstrating the use of a variety of teaching techniques and materials such as learning stations, bibliographies, print study guides, multimedia presentations, independent-study assignments, and individualized instruction;
d) advising science teachers about professional reference books, periodicals, films, videotapes, conferences, and workshops;
e) locating and acquiring materials, information, and assistance from the interlibrary loan service, the board's learning resource centre, educational associations and federations, faculties of education, and universities and colleges of applied arts and technology;
f) instructing students on strategies for gathering information;
g) evaluating students' use of learning resources;
h) supporting science teachers when they seek to provide special assistance to students who are exceptional, in bilevel or multigrade classes, in co-operative education, or taking courses through the Independent Learning Centre.

The use of resource-based learning may be judged to be effective for students when it:

a) improves their education by providing a variety of learning strategies;
b) facilitates their search for knowledge by matching kinds of resources to different learning styles and abilities;
c) provides reinforcement when different forms of media or materials on a topic are used;
d) provides opportunities to develop independent learning and problem-solving skills;
e) provides a dynamic and interesting process that allows them to use media and information technology in a meaningful way.

12.3 Textbooks and Learning Materials

Textbooks for science courses in the Intermediate and Senior Divisions are listed in *Circular 14*. Books selected for specific courses should meet a number of criteria. They should:

a) include all core units and an adequate selection of optional units;
b) be suitable for the level of difficulty intended;
c) be congruent with the objectives – attitudes, skills, and knowledge – outlined in this curriculum guideline;
d) be appropriate to the students' reading level;
e) provide a variety of formats for the outlining of student activities in the laboratory (the same format used consistently throughout a text is not necessarily beneficial);
f) include applications and societal implications;
g) contain references to accident prevention;
h) conform to accepted SI metric units;
i) include reading assignments within the text;
j) provide a balanced and scientific treatment of sensitive issues;
k) include a good variety of exercises and problems;
l) include exemplary samples of solutions to problems. The sample solutions should be characterized by consistent and accurate statements, whether verbal or mathematical, and the correct usage of units and symbols;
m) contain clear and accurate diagrams, charts, and graphs;
n) include enrichment material for the more capable students;
o) contain references to science as a human enterprise, with illustrations of notable achievements, including Canadian achievements, wherever appropriate;
p) include a career-awareness component related to science and technology;
q) be capable of motivating students to learn and enjoy science.

Learning materials other than science textbooks should also be evaluated carefully in terms of the criteria listed above, as well as those used to evaluate books for inclusion in *Circular 14*. These include conformity with the curriculum guideline and freedom from racial, cultural, sexual, and religious bias.

It is expected that a good textbook for most of the science courses described in this guideline will be essential to students' success in becoming familiar with the subject matter. While students should be encouraged to use a variety of resources for most assignments, one science text should be used predominantly for a given course. Copies should be available to all students for home study as needed. School boards are encouraged to give this matter high priority.

12.4 Calculators

Fingers, the abacus, logarithmic and trigonometric tables, and the slide rule are among the so-called mathematical crutches of the past. The calculator (particularly one with inverse, exponential, logarithmic, and trigonometric functions for Senior science) and the computer are the "crutches" of the modern world. We think of them as invaluable tools, and their use has become an integral part of science.

Since these machines do only what they are told to do, students need to be taught how to use them. Young scientists must understand what commands to give, how to give them, and why. They should also have a reasonable idea of what results to expect. Schools should, therefore, ensure that students become proficient in the use of calculators, particularly where boring mental calculations would waste time and detract from more beneficial uses of science periods and home study. Although the use of calculators should be encouraged, students should not be solely dependent on them for solving simple problems, especially those involving numerals with a small number of digits and some convenient factors. Calculators should be used primarily when large numbers of digits are involved, when the numbers do not factor readily, or when a large number of calculations are to be made.

In order for students to learn to think through a mathematical problem in science, it is generally recommended that they perform the algebraic work first, determine the mathematical operations that are to be performed, decide on the units to be used, and often estimate the answer *before* resorting to the use of the calculator.

When calculators are used, it is recommended that rounding be applied only when the final answer is determined and not at some previous stage. This practice will assure greater accuracy and consistency in stating final numerical results.

12.5 Computers

The computer plays a major role in science and should be seen as an essential component of the Intermediate and Senior Division science curriculum, at a time when postsecondary educational institutions are increasingly requiring computer knowledge for entry into science and engineering programs. As the cost of computer hardware decreases and the availability of good educational software increases, science teachers in both elementary and secondary schools will be able to provide students with new and exciting approaches to science education through the use of microcomputers.

The teaching of science can be greatly enhanced by the use of computers. They can assist in meeting the different needs of the students in a classroom. Gifted students can explore well beyond the regular curriculum, while handicapped students can work at their own pace. In conjunction with other teaching techniques, the computer allows the teacher a large array of approaches and the freedom to manage the classroom flexibly and creatively. Because students will be at varied levels of ability in terms of computer competence, the teacher should consider the possibilities and outcomes of peer teaching.

Science emphasizes problem solving, which includes such components as classifying and analysing information, concepts, and applications; storing, organizing, and retrieving data; graphing and manipulating variables; describing and explaining phenomena; and constructing and calculating quantitative problems. Computers allow students to create data tables, vary the data, plot the results, find mathematical relationships, store and retrieve information (both quantitative and qualitative), and process changes rapidly, without expending long periods of time in laborious and boring work. The computer allows more time for the creative learning of science.

Computers can provide large data banks of problems, ranging from simple to complex. This allows students to solve more problems than are traditionally available in textbooks, permits the development of more sophisticated problem-solving techniques and skills, and provides increased opportunities for diversity and enrichment.

Scientific searches for information (e.g., on animals, plants, characteristics of matter, types of forces, consumption of energy) frequently involve students in steps such as brainstorming, organizing ideas into clusters, showing interrelationships among the ideas (network or web), and organizing outlines of the ideas into a hierarchy to form a table of contents. Having completed these steps, students can then gather information in accord with the outline and form a data base. Computers enable students to add and delete entries, change format, arrange information in spreadsheet fashion, and continually access and retrieve data at high speeds. While using computers, students are challenged to think systematically and creatively, to investigate or search in an organized fashion, and to realign the processed information when new data are obtained. Computers can also record and process data through interfacing with traditional science equipment. Transducers, through analog to digital signal conversions, have been developed to measure such quantities as temperature, pH, voltage, and pressure.

Software programs can provide opportunities for students to:

a) work at their own pace;
b) practise a skill repeatedly until it is mastered;
c) learn some portion of the curriculum that they missed because of absence;
d) review a topic that they have forgotten or did not learn well;
e) try out a great variety of approaches or applications for a given problem or experiment;
f) experience enjoyment through science-related games;
g) tackle scientific investigations that normally could not be done in a laboratory because of the cost of the equipment, possible danger, or the length of time that would be needed to conduct the actual experiment rather than observe a simulation;
h) study and analyse very high- or low-speed phenomena by slowing down or speeding up the computer representation of such phenomena;
i) observe and examine ongoing changes that could be shown in a text only in static diagrams;
j) change the parameters of an experiment and almost instantly observe the resulting change;
k) obtain printouts of qualitative information, numerical data, and graphical representations for future reference.

Computers can be used to monitor students' work. Such monitoring can be done informally by the students themselves or more formally by the teacher, who can use the results as the basis for assigning pretests and posttests and for evaluating remedial, regular, or enrichment programs.

Education in remote areas can be established through computers for students who may have to study at home. Other forms of learning should be used to supplement computer programs if such students are to obtain a balanced program.

The inherent motivational and educational characteristics of computer utilization by students makes teacher literacy in this field an essential component of any preservice or in-service professional development program. Faculties of education and school boards should consider establishing strategies to assist teachers in this regard.

12.6 The Scientific Community

With rapid changes in science and technology and the creation of new employment roles and career paths for people working in science and related vocations, there is a need for educators to maintain contact with the science community.

From the perspective of elementary and secondary schools, this community includes local scientists, technologists, and technicians; individuals working in health and medical work, on engineering projects, in meteorology, and in weather broadcasting; those engaged in agriculture, forestry, and related areas; those whose work is concerned with the construction and manufacturing industries; those, such as psychologists, psychiatrists, and forensic scientists, whose work deals with behaviour; science and technology instructors in the universities and colleges; those who work in museums, science centres, observatories, and planetariums; those concerned with the design of transportation systems; those employed by local, provincial, and federal governments in work related to science; and those who read about and are interested in the world of science.

Science teachers should be the effective link between students and members of the science community, making students aware of science activities in the local area, science content in the media, and science achievements, including Canadian successes. Members of the science community should be invited to participate from time to time in the classroom experience. They may also react to the curriculum, add enrichment, provide resource materials, support co-operative education and work-experience programs, permit students to visit their areas of employment, and recommend employment opportunities.

A local science education council within a school board or group of boards can be established to permit interaction among science students, teachers, and community members. Such a council can stimulate enthusiasm for the scientific enterprise and make science courses more relevant to the world of work.

Section 13

Modes of Delivery

13.1 Bilevel and Multigrade Classes

Where enrolments are low, creative forms of timetabling rather than the curtailment of science courses should be considered in the best interests of students. For example, schools may choose to combine, in the same class, two groups of students who are working either at two different levels of difficulty or at two different grade levels.

When a bilevel or multigrade class is offered, the two courses should be kept quite distinct from one another. Care must be taken to ensure that individual course objectives are achieved at both levels or grades so that students receive the best possible program under the existing conditions. The specific course objectives, topics, student activities, applications, and societal implications must be identified clearly for both groups of students, and procedures for evaluating student achievement should be sufficiently distinct to meet the requirements of each course.

Particular care must be taken to ensure laboratory safety in bilevel and multigrade classes. Teachers should supervise all student activities and should not leave one group doing hazardous laboratory work in order to teach the other group. Individualized or small-group instruction modules can be incorporated into the program so that some students can work independently while the teacher is instructing or assisting others. More capable students can often help their peers and, in performing this tutorial role, will themselves benefit. Student contracts may also be used effectively in such classes. They should clearly identify all components required in each unit of study so that students fully understand the expectations that they are to meet. The contracts should also clarify the criteria and methods to be used to evaluate student achievement.

Extra time, energy, and dedication is required of science staff to adapt the curriculum guideline and to organize flexible and supportive work structures to accommodate bilevel or multigrade classes. School boards should consider the provision of special professional-development opportunities to help teachers acquire the skills they will require in managing such classes. The use of the resource centre and resource-based learning with the assistance of the teacher-librarian should prove to be of some help in this regard.

13.2 Co-operative Education

Co-operative education courses in science in Grades 9 to 12 at the three levels of difficulty can provide a mode of learning that takes advantage of scientific resources available in the community. Some students can benefit from experiencing the day-to-day realities of working in a science environment. Such courses should place special emphasis on career exploration and skill development.

Science teachers are responsible for assisting in the development of both the in-school and out-of-school components of the courses described in this guideline. They are responsible for teaching the in-school component and for co-operatively determining with the supervisor of the work station such features of the out-of-school component as its subject matter, resources, and evaluative criteria. The objectives, activities, applications, implications, and safety requirements for the out-of-school component must relate to and reinforce the in-school component. Thus, it is imperative that a qualified science teacher be involved in the co-operative design and monitoring of the out-of-school component of any science-related co-operative education program.

Any science course offered for credit purposes in Grades 9 to 12 and described in this guideline is normally based on a scheduled time period of 110 hours. A single-credit guideline course in science may be taught in the co-operative education mode, with up to two-thirds of the 110 hours, that is, a maximum of 73 hours, allotted to the out-of-school component and at least one-third, or 37 hours, allotted to the in-school component.

When a guideline course is expanded for purposes of co-operative education, the sum of the in-school and out-of-school components of the expanded set of science courses shall not exceed three credits, and that part in excess of one credit shall be identified as co-operative education credit work in science. For example, a student who takes Grade 11 biology for 330 hours, combining in-school work (one credit) with out-of-school experience in a hospital laboratory (two credits), may earn three credits. On the transcript one course would be identified as "Biology: 1 credit" and the other two as "Biology – Co-operative Education: 2 credits". The same course code, SBA3G, would be used for both entries. The out-of-school experience would be evaluated, as would the in-school component, on the basis of the educational objectives stated in this science guideline. For some science courses it may be especially appropriate to establish a two-credit package: one credit for the in-school component and one for the out-of-school component. This approach does not apply to science OACs, since they cannot be expanded beyond one credit and may not be taught in the co-operative education mode.

Further details governing co-operative education courses and credits are provided in subsection 5.11 of OSIS.

13.3 Program Packages

School-related packages. A school-related package may be designed to facilitate students' direct entry into employment or to train them in a particular area of study in order to prepare them for further studies in the particular area, such as technology in a college of applied arts and technology or engineering at a university. Such packages can provide a practical way of offering students a broad range of experience. Sometimes when enrolments are small and students are within reach of two or more neighbouring secondary schools, they can select the school that offers the package best suited to their needs.

A package should include related courses, usually at the same level of difficulty, that are offered in sequence over two or more years and are related to a subject field of concentration. Students may choose all or part of a package.

A package leading to engineering, for example, might include physics, chemistry, mathematics, computer studies, electric technology, drafting, and English/français. If all students in a given school who are contemplating the possibility of becoming engineers participate in such a program, special academic and practical features such as scientific report writing, physics and chemistry engineering applications, practical computer programs, and numerous technological applications and societal implications could become important elements of the package.

Another package, one in which science would play a lesser role, might concentrate on technological studies and be directed towards immediate employment after Grade 12. Such a package, for example, might have auto mechanics as the subject of concentration and could include courses in small engines, machine technology, electricity, applied physics, mathematics, accountancy, and English/français. Students taking this package could also benefit from work experience or co-operative education in conjunction with the curriculum.

Further details on school-related packages are supplied in subsection 5.9 of OSIS.

Community-related packages. A community-related package focuses on a curricular emphasis related to a major economic base in the community. A science-oriented package might include forestry, mining, or agriculture in a community where natural resources exist; the production of steel, plastics, petroleum, or chemicals in an industrial area; or health sciences in an area where there are large hospitals, nursing homes, nutrition centres, and health spas. Joint planning, implementation, and evaluation of a community-related package by teachers and representatives of the local community should ensure that the program is relevant to both students and the community. Community-related packages may include courses at different levels of difficulty.

When a science course or courses become part of such a package, a deliberate attempt should be made to refer frequently to the community focus. The objectives, student activities, applications, societal implications, problem-solving components, and career-awareness aspects of a course can often be directed towards the community without compromising the main aims of the science curriculum.

Where the course content in any community-related package deviates from curriculum guidelines, Ministry of Education approval shall be required for the establishment of the program.

For further details on community-related packages, see subsection 5.10 of OSIS.

13.4 Adult Education

As employment requirements become more demanding, many adults are returning to school to upgrade their education or to acquire specific skills to help them function more effectively in the world of work. They may attend day-school programs on a full-time or part-time basis or enrol in continuing education courses in science in summer school, evening classes, or in daytime continuing education courses.

In day schools that admit adults science courses may be offered to classes in which teenagers are integrated with adults or in which only adults are enrolled. Science courses in the regular day-school program taken for credit by classes in which there is a mix of teenagers and adults shall not be less than 110 hours. While courses taken exclusively by adults may be completed in 90 hours (see OSIS, subsection 6.6), it is strongly recommended that such courses be scheduled for 110 hours because of the mandatory student activities in laboratory work.

In planning classes for adults, teachers should remember that the following characteristics of students are particularly true of adult learners. Adults:

a) bring a wealth of practical experiences with them, and their personal experiences that are related to the course should be used to enrich the learning process;
b) frequently learn best in small groups and welcome the support of their peers;
c) learn effectively through active involvement and need a good balance between hands-on activities and the more theoretical and abstract components of science; in fact, the mandatory student activities apply to them as much as they do to regular day-school students;
d) as a rule, tend to be problem-oriented and to focus on the present. Because of their other adult responsibilities they expect their time in class to be well utilized;
e) are concerned that what they learn be of relevance to them in the working world;
f) exhibit a wide range of learning styles. Some may have a lot of catching up to do, while others may want to forge ahead at an accelerated rate. Independent student modules or individualized or small-group-work projects, which should be matched to their individual differences, may be used to facilitate their progress.

Adult learning theory suggests that most adults returning to school tend to be highly self-directed, responsible, and mature. The teacher must decide the extent to which the principles described above may be implemented. Teaching methodology and program organization is described in *Adult Learning Principles and Their Application to Program Planning*, a research report available from the Ontario Government Bookstore, 880 Bay Street, Toronto, Ontario M7A 1N8. Reference may also be made to *Continuing Education: A Resource Document* (Toronto: Ministry of Education, Ontario, 1987).

13.5 Independent Learning Centre

The Independent Learning Centre of the Ministry of Education confers credits towards an OSSD when students have successfully completed correspondence courses. Many science courses can be taken through this mode of learning. Information on eligibility and enrolment procedures may be obtained from the Independent Learning Centre, Ministry of Education, 909 Yonge Street, Toronto, Ontario M4W 3G2.

13.6 Specialized Schools

A school board or set of school boards may wish to establish a secondary school that focuses predominantly on pure and applied science. Such a school would offer a program that would enable students to earn credits in the compulsory subjects for the OSSD and also a variety of science and science-related electives. The school would provide opportunities for specialized work and might well meet the particular needs of those students who have a strong interest in and a high aptitude for this area. A proposal to establish a school of pure and applied science should be submitted to the Ministry of Education for discussion and approval. (See OSIS, subsection 5.15.)

Section 14

Evaluation

This section deals with the evaluation of guideline-implementation progress, student achievement, teacher performance, and program effectiveness. The following policy relates directly to these topics:

1. In the overall assessment of student achievement in all Intermediate and Senior Division science courses, including the OACs, there shall be a component for laboratory work. This shall be allotted at least 15 per cent of the final mark and is to include an evaluation of students' ability and skills during laboratory activities as well as an evaluation of their written reports.
2. Each student who wishes to complete successfully a science OAC shall write at least one formal examination in that OAC. A student may not be exempted except in cases of emergency or illness. The examination(s) for each science OAC shall be allotted at least 30 per cent, but not more than 40 per cent, of the final mark. If only one examination is used towards the evaluation of student achievement for an OAC, it should be based on more than one-half of the course (preferably on most of the course).
3. At least 10 per cent of the overall evaluation for each science OAC shall be allotted to work done through independent study. In the glossary of terms given in Appendix A of OSIS, independent study is described as "an arrangement by which a student is excused from attending some or all classes in a course to study independently, but under the supervision of the teacher". In the science OACs, independent study is required for only a small portion of each course. Exemption from class attendance shall be monitored by the teacher, who is responsible for assigning components of the course, suggesting available resources, and evaluating student achievement. If the independent-study assignment includes laboratory work, such work shall be per-

formed under the direct supervision of the teacher. Specific details regarding independent study in the OACs are given in the course descriptions of the respective courses. Independent study is addressed in subsection 6.3 of OSIS.

14.1 Evaluating Guideline-Implementation Progress

There are three forms of science curriculum:

- The *intended* curriculum is described in this guideline and indicates the expectations of the Ministry of Education.
- The *translated* curriculum is the teacher's interpretation of the curriculum based on what he/she hopes to achieve in the classroom.
- The *achieved* curriculum is the science that students actually learn.

Evaluating implementation progress involves the process of trying to measure how well the intended curriculum is finally achieved. The first stage is to have administrators and teachers receive the curriculum guideline and translate it into a program that can be implemented in the classroom.

A board plan for evaluating the progress of guideline implementation should be developed. The plan can be based on the following suggestions:

1. A chart of the various steps that should be planned for can be made. These steps include:
   a) providing administrators and principals with an overview of the science guideline;
   b) identifying areas of responsibility for supervisory officers, science co-ordinators, principals, heads of science, and teachers;
   c) determining overall policies that affect implementation of the science program (e.g., budget and staffing);
   d) deciding what courses are to be offered at each school;
   e) preparing teachers, under a well-defined schedule, for changes in the program;
   f) writing locally developed curriculum resource documents for the science program;
   g) phasing in the new and revised courses over a suitable number of years;
   h) selecting appropriate textbooks and resources;
   i) purchasing needed equipment;
   j) developing courses of study and course outlines;
   k) informing students and their parents about the science program;
   l) considering teaching methodology for all science courses, including features such as laboratory work, seminars, field studies, adaptations for exceptional students, co-operative education, the use of plants and animals, resource-based learning, individualized instruction, computer education, the inclusion of sensitive issues, language development, and career awareness;
   m) evaluating student achievement;
   n) evaluating program effectiveness.
2. The following can also be indicated on the chart:
   a) the anticipated time lines for each of the above steps;
   b) the person(s) responsible for overseeing each step;
   c) the personnel who will be affected in implementing each step;
   d) the approximate costs and other resources that are needed.
3. The chart can include provisions for:
   a) some indication of the progress and completion of each step;
   b) an assessment of the various steps that are achieved;
   c) comments that may help in implementing future courses;
   d) areas on which feedback may be made to principals, supervisory officers, the school board, and the Ministry of Education.

14.2 Evaluating Student Achievement

1. Major Functions of the Evaluation of Student Achievement

The evaluation of student achievement provides:

a) information for teachers to help them identify students' needs and to assess the progress of students' development of skills, understandings, attitudes, and interests;
b) information for students about their mastery and growth and their strengths and limitations;
c) a basis for grading students, reporting their progress, and helping them set realistic goals for future undertakings;
d) information that can be used to help revise teaching strategies and the curriculum.

The process of evaluation must relate to the objectives of the curriculum, with an appropriate balance between content and process. The objectives must relate to the aims of the science curriculum (see subsection 3.1) and ultimately to the goals of education (see section 2).

2. Types of Evaluation of Achievement

In general, evaluation can be considered under three forms or types: diagnostic, formative, and summative.

Diagnostic evaluation normally precedes instruction but may also be used during a unit of study. The resulting information should act as a basis for remedial work, adjustments in instruction, or enrichment for some students. Special aspects such as students' reading comprehension of a science textbook or their ability to do mathematics may require particular diagnosis.

Formative evaluation provides pertinent feedback on recent student performance and program effectiveness. It allows students to make immediate improvements during their term work. Success will provide students with positive motivation; continuous failure on the part of some students should alert the teacher to the special needs of these students.

Formative data often direct teachers to introduce curriculum improvements, to define goals on a more realistic basis, or to adjust standards to new levels. Formative evaluation should do what the word *formative* implies, that is, help form or reshape students' learning throughout the instructional process.

Formative evaluation may be based on students':

a) class tests on a small portion or the whole of a unit of study;
b) homework assignments;
c) laboratory performances and reports;
d) science notes;
e) observed proficiency in scientific processes (e.g., classifying);
f) performance of specific psychomotor skills;
g) problem solving;
h) oral presentations;
i) short projects;
j) answers to informal questioning related to specific objectives;
k) use of language;
l) general attitude and behaviour.

Summative evaluation helps to sum up overall progress and takes place at the end of a course or a substantial portion thereof. Report cards with their assigned grades provide evidence of summative evaluation, reflecting reliable information on student achievement based on both formative and summative assessment.

Summative evaluation may be based on:

a) formal examinations;
b) class tests that cover two or more full units of study;
c) extensive laboratory tests based on work covered in the current month or more;
d) extended projects;
e) written reports of a fairly comprehensive nature; a series of short reports are usually far more valuable than a single lengthy report;
f) problem solving in which the solution depends on knowledge acquired from several units of study (e.g., a mechanics-electricity problem in physics).

It is recommended that teachers' assessments of student achievement be based on a combination of diagnostic, formative, and summative evaluation. At the basic level the emphasis should be placed on diagnostic and formative evaluation. At the general level, particularly for students intending to proceed to colleges of applied arts and technology, some summative evaluation should complement formative evaluation. At the advanced level there should be a balance between formative and summative evaluation.

3. Methods of Evaluating Student Achievement

Any assessment plan should include a variety of evaluation methods. A broad range of types of questions will give a more realistic profile of student ability than will a limited range.

Norm-referenced evaluation, based on ranking students with others in their group, leads to "grading on the curve" and is strongly influenced by the ability of the peer group. This form of evaluation has limited meaning unless applied to large random populations of students with natural ranges of abilities. It is sometimes useful in judging the difficulty of a test rather than the achievement of individual students.

Criterion-referenced evaluation involves grading students on their attainment of curriculum objectives according to predetermined levels of performance. This type of evaluation is useful but is very subject-oriented. It poses problems for students who "fail" and are held back to repeat their attempts to "jump the hurdle". It requires careful consideration by the teacher, who must maintain the integrity of science and at the same time meet the needs of students who have difficulty with the subject.

Individualized ability evaluation involves judging a student's achievement in terms of his/her own ability. The use of this method requires students with high ability to achieve more than those with less in order to receive the same percentage grade. It may prove to be particularly useful with students who have special learning needs or who are working in basic-level or general-level courses. This method may also take the form of contract grading in cases where individualized instruction or student contracts are used.

A combination or modification of the above three methods should be used in different proportions for the various levels of difficulty. For example, in basic-level courses individualized ability evaluation might be emphasized, while in advanced-level courses criterion-referenced testing might be stressed; however, the methods should be used in combination in most science courses.

Teachers should have well-thought-out plans for the evaluation of student achievement and should let students know well in advance how they are to be evaluated and how final grades will be determined. (See also subsection 10.2, point 8.) Parents, principals, and supervisory officers should be able to receive an explanation of how student grades are determined.

4. Kinds of Evaluation Techniques

In the evaluation of student achievement, test items are to be related to the objectives – attitudes, skills, and knowledge – outlined in all of the course descriptions that appear in this guideline. Table 7 should be useful in considering the objectives and their relationship to evaluation.

Table 7: Evaluation Objectives

Kinds of Objectives	Aspects to Be Evaluated
Attitudinal (affective domain)	Interest in science and technology values related to the nature of science; concern for safety; respect for the environment; wise use of energy; co-operation and behaviour
Skill (psychomotor domain)	Laboratory skills and processes; application of accident-prevention knowledge and techniques; field-study techniques
Knowledge (cognitive domain)	Recall of information and concepts; comprehension of new ideas; application of scientific principles; analysis and synthesis of data and explanations; evaluation of techniques and theories; problem solving; communication, decision-making, and creative skills

Many learning outcomes involve an overlap of attitudes, skills, and knowledge. The approach used in the classroom will often clarify whether an outcome is achieved through one kind of objective or a combination. Scientific processes such as measuring, classifying, experimenting, hypothesizing, generalizing, analysing, and synthesizing are examples of situations in which the kinds of objectives may vary greatly from one classroom approach to another. The main point here is to recognize the three major learning domains and to place some emphasis on all three when evaluating student achievement. It should be noted that the evaluation of student attitudes is likely to be highly subjective. However, students should realize that attitudes are a most important aspect of science education, which should be taken into account in the overall assessment of their work.

A great variety of kinds of questions or methods of evaluation should be adopted. Table 8, modified from Rodney L. Doran's summary in *Basic Measurement and Evaluation of Science Instruction* (Washington, D.C.: National Science Teachers' Association, 1980), might serve as a guide in considering various ways of collecting data on student progress.

Table 8: Evaluation Techniques

Form of Technique		Kinds of Possible Evaluation Items
Test	paper-and-pencil	multiple-choice; true/false; matching; essay; problem-solving
	pictorial	diagrams; graphing
	laboratory-performance	range of activities, from following instructions to designing an experimental investigation
	open-book	understanding of text; summarizing
	take-home	assignment; project
Observation	checklist of skills	care of equipment; laboratory design and techniques; safety awareness; class participation; general co-operation
Inventory	questionnaire	finding facts, data, opinions
	rating scale	ranges of opinions
Product analysis	science notes reports projects essays	organization; accuracy; clarity; neatness; completeness; use of language; readability; graphing; diagrams; charts

Some of the techniques listed in table 8 will be implemented in a straightforward manner (e.g., through written tests). In other cases checklists might be used to evaluate key behaviours and actions. Analyses of laboratory reports, projects, short essays, and independent study can provide a wealth of information on student performance, preferences, awareness, opinions, attitudes, and values. Such analyses usually require extensive evaluation criteria and therefore add to a science teacher's workload. However, the value of the experience for most students is essential and rewarding. Peer and self-evaluation can motivate students to develop self-respect and respect for other students. The teacher should ensure that such evaluation is positive and constructive. Particular attention should be given to variety in evaluation for students with disabilities (see subsection 6.2, point 9).

The Ontario Assessment Instrument Pool (OAIP), developed by the Ministry of Education, provides a great variety of kinds of questions for teachers to use not only in evaluating student achievement but also in teaching students how to answer questions effectively and how to study to achieve educational objectives. At the time of the printing of this document, the OAIP includes instrument pools for Senior biology, chemistry, and physics, and several thousand items are under development for use in science in the Intermediate Division.

The OAIP in science is achieving widespread recognition as one of the foremost banks of science items available anywhere. The newly developed OAC biology pool is based on the course described in this guideline. The OAC chemistry and physics pools contain thousands of items that are appropriate for the new OACs, although they were based on former guidelines. Teachers who have availed themselves of these chemistry and physics evaluation instruments have invariably found them to be an excellent collection of highly reliable and effective items.

In the past the OAIP science pools tended to contain a majority of objective-type questions, but now they consist of a great variety of instrument types within a wide range of categories. A current example under development is the Intermediate Division science OAIP. It will contain several thousands of items and will be keyed to every objective listed in the relevant course descriptions given in this guideline. All of the items are classified according to a series of "instrument types" (e.g., multiple-choice, numerical-problem, completion, and laboratory-skill). The science OAIP also contains an array of "learning domains" based on categories of objectives proposed by Klopfer and modified for use with the OAIP. Such domains include observing and measuring, seeing a problem and ways to solve it, attitudes and interests, and science orientation, to mention a few. The instrument types and learning domains presently being used to help organize the Intermediate Division science OAIP are listed in Appendix E. This new OAIP has tremendous potential as a resource for science teachers seeking to evaluate student achievement.

5. Evaluating Science Laboratory Skills

Although this curriculum guideline requires students to perform laboratory activities in all science courses, unless such work is evaluated, students are likely to feel that it is unimportant. The evaluation of laboratory skills needs special attention and a definite plan of implementation if it is indeed to become a reality in the science program. For this reason science teachers should carefully consider the following suggestions:

1. Laboratory work should be evaluated by means of a criteria checklist, with a selected number of students being observed during each laboratory experience; as well, some time in each course should be set aside for a few laboratory tests.
2. When making a checklist to use for the observation of student performance, the teacher should attempt to include cognitive, psychomotor, and affective objectives. Observational assessment through the use of a written checklist ensures a greater breadth of skill evaluation than can be accomplished without a good comprehensive list. The checklist can also be used over an extended number of laboratory activities, with different items being observed in each activity.
3. The evaluation of cognitive objectives can include assessment of students' scientific knowledge and processes; their understanding of instructions, vocabulary, and formulas; their application of the scientific method; their development of new or creative methods to investigate problems; and their ability to organize tables, draw graphs, and write laboratory reports.
4. Students' attainment of psychomotor-skill objectives can be evaluated on the basis of their handling of equipment, the accuracy with which they make measurements, the quality of their laboratory performance, and their attention to safety.
5. Students' attitudinal or affective skills can be evaluated by observing their interest and enthusiasm, initiative, pursuit of excellence, confidence and pride in work well done, respect for learning, and communication and co-operation with others.
6. Many laboratory activities will require students to follow explicit directions, and the evaluation of such ability is important. However, a good experimental program will go further. From time to time, students should also be evaluated on their ability to propose a hypothesis, to design their own method of attacking an investigation, to select an appropriate testing procedure, to determine what data to collect, and to decide how best to present their laboratory report. Originality should be encouraged, particularly in the writing-up of laboratory reports.

7. The evaluation of laboratory skills should include the assessment of how well students carry forward the hypotheses, procedures, and results from previous activities and apply them in new problem-solving situations.

8. Laboratory activities contain certain phases, and student performance can be evaluated by observing one particular phase at a time or a sequence of phases when students have gained adequate experience. These phases can be thought of as (a) the planning and design phase, (b) the performance phase, (c) the analysis and interpretation phase, and (d) the application or outcome phase.
   a) The planning and design phase can be evaluated by seeing how well students select a problem, formulate investigative questions, formulate a hypothesis, predict results, decide on variables, and design their experimental procedures.
   b) The evaluation of the performance phase can include the assessment of students' technique, organization, neatness, efficiency, collection of appropriate data, psychomotor proficiency, care and storage of equipment, and attention to accident prevention.
   c) The analysis and interpretation phase provides opportunities for the teacher to evaluate student ability in processing data, outlining assumptions and limitations, examining the accuracy of measurements, identifying experimental error, explaining relationships, reaching conclusions, developing generalizations, and formulating new questions.
   d) The application phase can be evaluated as students seek to derive new hypotheses that may emerge from an investigation, predict new results, apply techniques to further investigations, and relate concepts to real-world applications in daily life and technology.

9. The roles that students assume in a laboratory activity can be observed and evaluated. Their abilities to take initiative, accept responsibility, show leadership, be co-operative, and vary their roles (e.g., from active participant in one experiment to reader of observations in another) can serve as criteria for evaluation purposes.

10. Students' written laboratory reports can serve as an effective basis for the evaluation of their activities in science, but they must not be used exclusively. Evaluating laboratory work solely on the basis of reports will encourage the copying of reports and the falsifying of data. Writing skills and language development should be assessed when reports are marked.

11. Test items on laboratory work should be given to students throughout a course, and once in a while a test consisting exclusively of a laboratory investigation should be included.

12. One form of laboratory test is the "procedural step model", in which students may be given or asked for specific procedural steps to be used in the activity. The student is then asked to design additional procedures to complete the investigation. The chemistry OAIP contains examples of this model.

13. Another form of laboratory test is the "clue model", which allows for a considerable degree of student inquiry and inventiveness. The student may ask for or be given a series of clues that he/she could use to design a laboratory procedure to solve the problem at hand. In this form, the clues are *not* specific steps in the laboratory procedure, but they may generate ideas that lead to such steps. Again, the chemistry OAIP contains examples of this model.

14. Teachers are well advised to investigate literature on laboratory test instruments. For example, the physics OAIP contains a complete section on this topic, including the following subsections: Laboratory Exercises, Scoring Scheme for Formal Laboratory Reports, Laboratory-Skill Test With Examples, Administering Laboratory Test Instruments, Scoring Laboratory Test Instruments, Matching Evaluation Instruments or Objectives.

14.3 Self-Evaluation of Teacher Performance

Self-appraisal, although difficult, is essential for professional growth. This process consists in sincerely asking oneself a series of appropriate questions, honestly facing the answers, and then seeking to improve one's personal performance.

The following are among the many questions that science teachers might ask themselves about their own performance:

a) Is my version of the *translated* curriculum in my classroom closely related to the *intended* curriculum of the Ministry of Education?
b) Through my teaching is the *achieved* curriculum – that mastered by my students – closely related to my *translated* curriculum?
c) Regarding the subjects I teach, have I built a personal, sound knowledge, renewing and extending it continually (to other sciences or related subjects) and reaching beyond habitual and mediocre levels?
d) Do I do what I expect of my students: observe phenomena, investigate and think, ask questions of myself, read widely, grow with the changing times, display originality, and maintain the spark of curiosity?
e) Am I inspired and inspiring – giving of myself, having a sense of mission, caring about each student, and fostering in them a desire to learn and to develop their own powers and values?

f) Do I ever ask my students what they like and dislike about my teaching, about the laboratory, or about our mutual interaction?

g) Do I ever observe another teacher teach, participate actively in science teachers' associations, mix with practising scientists and technologists, and seek other ways of developing professionally?

h) Do I have a code of ethics, particularly in regard to my being a role model for my students in such areas as morals and values education, sex equity, multiculturalism, student management, interaction with other adults, maintenance of personal fitness and appearance, attitudes towards sensitive issues, interest in career awareness, understanding of the applications and societal implications of science, conservation of energy resources, and respect for the environment and for living things?

Many teacher-evaluation questionnaires exist, and these often deal with a set of detailed points about the teacher's appearance, chalkboard outlines, lesson development, and so on. Some questionnaires have been prepared to be answered by students. For example, the "Teacher Credibility Questionnaire" contained in *Science, Students, and Schools* by Ronald D. Simpson and Norman D. Anderson (New York: John Wiley and Sons, 1981) permits students to rate their science teacher on a scale of 1 to 5 on such points as whether the teacher listens to criticisms about the lesson, lets students know how well they are doing in class, and is skilled in the subject. Such questionnaires are *not* intended to be used by supervisory officers or principals. They should be used only on the initiative of the individual teacher on a voluntary basis.

14.4 Evaluation of Program Effectiveness

Evaluating the effectiveness of the science program consists of judging its worth on the basis of valid information about how well the achieved curriculum meets the objectives of the intended curriculum. This means that the worth of the program must be assessed on the basis of how effective it has been for students in the science program. Where a team is involved in evaluating program effectiveness, it is advisable to include one or more "outsiders" if available. (For example, neighbouring boards might establish an exchange.)

Many sources of data should be searched to provide a basis for the evaluation of a science program. Such sources include the following:

a) formative and summative evaluation of student achievement

b) an analysis of the methods of evaluation and the kinds of evaluative instruments used

c) questionnaires that sample teachers' goals, strategies, and emphases

d) classroom observation of teaching strategies and student responses

e) records of actual time spent on each unit of study in comparison with the recommended time allocations

f) comparisons of local goals in science with the aims of the science curriculum as stated in section 3 of this guideline as well as the general goals of education stated in section 2

g) comparisons of locally achieved objectives with those listed in the course descriptions in Parts 2 to 15 of this guideline

h) questionnaires and interviews to ascertain how students feel about the science program and its effectiveness in meeting their needs, interests, and abilities

i) questionnaires and interviews to determine the goals and expectations of the community

j) criteria used for recommending program choices to students and the modification of such criteria to suit the needs of individuals

k) records of student enrolment, dropouts, and holding power in science over a period of several years

l) comparative enrolments of girls and boys in the various science disciplines

m) analyses of the availability and use of resources, such as library resource centres, laboratory facilities, scientific equipment, and safety features

n) analyses of the availability and use, particularly for homework assignments and study, of textbooks and other learning materials

o) analyses of the availability and use of calculators and computers

p) school board practices and policies in regard to science co-ordinators, staff attendance at science conferences, local science-curriculum resource guides and other resources, field trips and industrial tours for students, co-operative education and work experience in science courses, and the maintaining of animals and plants in schools

q) comparisons of local student achievement (using large groups and preserving anonymity) in science with that in other schools, boards, provinces, and nations

r) enrolments in science and success rates of local graduates who proceed to college or university

s) questionnaires that seek impressions from first- and second-year college and university students and faculty of the value of Senior secondary school science courses

t) assessments of particular features related to mandatory student activities in the laboratory, the inclusion of applications and societal implications, emphasis on career awareness, the attention to language development in science, and the treatment of sensitive issues

u) analyses of teacher expertise in science, the preparation of teachers for changes in the curriculum, and the ongoing professional development of science teachers

School boards should welcome and co-operate in regional and provincial reviews of science programs, since an outside opinion of program effectiveness may shed new light on what is being accomplished.

Program evaluation should result in the implementation of improvements in such areas as the following:

a) teaching strategies
b) evaluation and assessment practices
c) local curriculum development
d) resources: laboratory, equipment, textbooks, and other items
e) the appropriateness and maintenance of standards
f) provisions for individual student needs, interests, and abilities
g) the interface between the schools and the community
h) the professional development of science teachers
i) the provision of feedback on curriculum development and related issues to the Ministry of Education

The evaluation of guideline-implementation progress, the assessment of student achievement, the self-evaluation of teacher performance, and the evaluation of program effectiveness should contribute to the creation of a learning environment in which each student and educator is encouraged to strive for full realization of his/her potential.

Appendixes

Appendixes

- A. Science Courses and Their Course Codes
- B. Physical Quantities
- C. Metric Editorial Practice
- D. Some Poisonous Plants
- E. Some OAIP Instrument Types and Learning Domains

Appendix A

Science Courses and Their Course Codes

The secondary school guideline courses in science authorized under this document have the following course codes:

Science, Grade 9, Basic Level	SNC1B
Science, Grade 9, General Level	SNC1G
Science, Grade 9, Advanced Level	SNC1A
Science, Grade 10, Basic Level	SNC2B
Environmental Science, Grade 10, General Level	SEN2G
Science, Grade 10, General Level	SNC2G
Environmental Science, Grade 10, Advanced Level	SEN2A
Science, Grade 10, Advanced Level	SNC2A
Science, Grade 11, Basic Level	SNC3B
Applied Biology, Grade 11, General Level	SBA3G
Applied Chemistry, Grade 11, General Level	SCA3G
Environmental Science, Grade 11, General Level	SEN3G
Biology, Grade 11, Advanced Level	SBI3A
Chemistry, Grade 11, Advanced Level	SCH3A
Science, Grade 12, Basic Level	SNC4B
Environmental Science, Grade 12, General Level	SEN4G
Geology, Grade 12, General Level	SGE4G
Applied Physics, Grade 12, General Level	SPA4G
Environmental Science, Grade 12, Advanced Level	SEN4A
Geology, Grade 12, Advanced Level	SGE4A
Physics, Grade 12, Advanced Level	SPH4A
Technological Science, Grade 12, General Level	STE4G
Biology, OAC	SBI0A
Chemistry, OAC	SCH0A
Physics, OAC	SPH0A
Science in Society, OAC	SSO0A

The following general rules govern science course codes:

- All science course codes begin with an **S.**
- **SNC** identifies a course that has only the name "Science".
- Where one word other than "Science" describes the course, the first two letters of that word follow the **S** (e.g., **SBI** means "Science, Biology" or simply "Biology"; **SEN** means "Science, Environmental" or "Environmental Science").
- Where two words other than "Science" describe the course, the initial letters of those words are used (e.g., **SCA** means "Science, Chemistry Applied" or simply "Applied Chemistry").
- The fourth character in the course code, **1**, **2**, **3**, **4**, or **0**, represents Grade 9, 10, 11, 12, or an OAC respectively.
- The fifth character represents the level of difficulty: **B** for basic, **G** for general, or **A** for advanced.

For further information on course codes, refer to the *Manual for the Common Course Code* (Toronto: Ministry of Education, Ontario, 1986).

Appendix B

Physical Quantities

This appendix indicates the majority of SI metric units to be used in science courses, some non-SI units that are permitted for use with SI, and some metric units that are no longer permitted.

Table 1 below lists many physical quantities in various categories. Once they are mentioned, they are not repeated in a later category unless some new feature or symbol is introduced. Some names of quantities are not included (e.g., circumference and perimeter), but the table should serve as a useful guide and provide for greater consistency in the use of units and symbols.

The units shown in columns 3, 5, and 6 are among those to be adopted for predominant use in school science. Those shown in column 5 may be extended to include additional multiples or submultiples if these are justified on the basis of practical or pedagogical importance. For example, the decimetre (dm) is rarely needed for measuring length. However, it is useful in explaining the relationship of the litre to the cubic decimetre.

The symbols for all units of measure are printed in upright or roman type (as shown in columns 4, 5, and 6). Each unit symbol in SI is unique in its application, as the following examples illustrate:

- The symbol "s" means "second"; hence, "s" is never used to pluralize unit symbols.
- The symbol "m" means "metre" when it appears alone or is preceded by a prefix as in "cm" (centimetre).
- The symbol "m" can also mean "milli" but only when used as a prefix, as in "mg" (milligram) or in "mm" (millimetre).
- The symbol "Pa" represents "pascal", and the symbol "mol" represents a "mole" of substance.
- More complex symbols exist, such as "kg·m²/s", which represents the "kilogram metre squared per second".

The unit symbols are international and do not vary from one language to another. They are not abbreviations. As *symbols* they can be multiplied, as in N·m (newton metre); divided, as in m/s (metre per second); and raised to a power, as in cm^3 (cubic centimetre).

Quantity symbols (see column 2) are printed in sloping or italic type to distinguish them from unit symbols. Thus, *m* means "mass" while m means "metre" and *F* means "force" while F means "farad". The use of the quantity symbols is recommended. Such symbols are not explicitly part of SI but are recognized by the International Organization for Standardization and are intended for adoption in Canada in accordance with the *Canadian Metric Practice Guide*.

Quantity symbols are not necessarily unique. For example, the sloping symbol *d* may represent distance or diameter, and *E* may stand for energy, modulus of elasticity, or electric field strength.

Although the quantity symbols shown in column 2 are recommended, there may be times, such as the following, when other quantity symbols are more appropriate:

- English symbols may be used in place of Greek symbols for Grades 7 to 10 and basic-level courses:
  - D for density (in place of the Greek letter ρ)
  - i and r for angles of incidence and reflection (instead of θ_1 and θ_2)
- The use of upper- and lower-case letters in a single problem may differentiate between two similar quantities:
  - H and h for heights (as in $d = H - h$)
  - R and r for radii [as in $A = \pi(R^2 - r^2)$]
- The use of subscripts or primes can help in representing several similar quantities:
  - v_1, v_2, v_3
  - E, E', E''
- Modifiers may be placed immediately after quantity symbols in the subscript position (never after a unit symbol) to differentiate between similar quantities:

E_P (potential energy)	E_H (heat energy)
E_K (kinetic energy)	E_E (electrical energy)

Table 1: Physical Quantities and Their Units*

(1) Name of Physical Quantity	(2) Quantity Symbol	(3) Name of SI Unit	(4) SI Unit Symbol	(5) Selection of Multiples and Submultiples of SI Units		(6) Other Units Permitted for Use With SI		(7) Notes
Space and Time								
length		metre	m	km		M	nautical mile*	1
► length	l			cm		AU	astronomical unit*	2
► breadth	b			mm				
► width	w			μm	micrometre*			3
► distance	d			nm	nanometre*			4
► path length	s							
► height	h							
► thickness	t							
► radius	r							
► diameter	d							
area	A	square metre	m^2	km^2		ha	hectare*	5
				dm^2				
				cm^2				
				mm^2				
volume	V	cubic metre	m^3	dm^3		L	litre*	6
				cm^3		ML	megalitre	
						kL		
						mL		
time	t	second	s	ks		d	day	
				ms		h	hour	
				μs		min	minute	
						a	year*	7
speed, velocity	u, v, c*	metre per second	m/s	cm/s		km/h		8
				mm/s		kn	knot*	9
acceleration	a, g*	metre per second squared	$\mathrm{m/s}^2$	$\mathrm{cm/s}^2$				10
plane angle	$\alpha, \beta, \gamma, \theta, \phi$	radian	rad	mrad		°	degree*	11
						′	minute	
						″	second	
						r	revolution	
angular velocity	ω	radian per second	rad/s*					12
angular acceleration	α	radian per second squared	$\mathrm{rad/s}^2$*					12

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* For many of the quantities or units in the table there are particular points with which science teachers should be familiar. Such points are identified by asterisks and appear in the notes at the end of the table as indicated by the numbers in column 7.

(1) Name of Physical Quantity	(2) Quantity Symbol	(3) Name of SI Unit	(4) SI Unit Symbol	(5) Selection of Multiples and Submultiples of SI Units	(6) Other Units Permitted for Use With SI	(7) Notes
Periodic and Related Phenomena						
period periodic time*	*T*	second	s	ms μs	min minute h hour d day	13
frequency	*f*, *ν*	hertz	Hz*	MHz kHz		14
rotational frequency	*n*	reciprocal second	s^{-1}	min^{-1}	r/s* r/min*	15 15
angular frequency	*ω*	radian per second	rad/s*			12
wavelength	λ	metre	m	mm μm nm nanometre* pm picometre		16
Mechanics						
mass*	*m*	kilogram	kg	Mg g mg	t metric ton or tonne*	17 18
density	*ρ*	kilogram per cubic metre	kg/m^3	g/cm^3* g/dm^3	g/mL* g/L	19
momentum	*p*	kilogram metre per second	kg·m/s			
force*	*F*	newton	N	MN kN mN		20, 21
pressure	*p*	pascal*	Pa	GPa MPa kPa	mbar millibar*	22 23
moment of force, torque	*M* *T*	newton metre*	N·m	MN·m kN·m mN·m		24
moment of inertia of mass	*I*	kilogram metre squared	$kg·m^2$			
moment of momentum*	*L*	kilogram metre squared per second	$kg·m^2/s$			25

(1) Name of Physical Quantity	(2) Quantity Symbol	(3) Name of SI Unit	(4) SI Unit Symbol	(5) Selection of Multiples and Submultiples of SI Units	(6) Other Units Permitted for Use With SI	(7) Notes
second moment of area	I_a	metre to the fourth power	m^4	mm^4*		26
stress		pascal*	Pa	GPa		22
▸ normal	σ			MPa*		27
▸ shear	τ			kPa		
modulus of elasticity*	E	pascal*	Pa	GPa		22
				MPa*		27, 28
				kPa		
surface tension	σ	newton per metre	N/m	mN/m		
mass flow rate	q_m	kilogram per second	kg/s	g/s		
volume flow rate	q_V	cubic metre per second	m^3/s	dm^3/s	L/s	
				cm^3/s	mL/s	
energy, work	E, W	joule*	J	GJ MJ kJ		29
power	P	watt	W	GW MW kW		
Heat						
thermodynamic temperature	T	kelvin*	K			30
Celsius temperature	t	degree Celsius*	°C			30
linear expansion	α	reciprocal kelvin or	K^{-1}	MK^{-1}		
		reciprocal degree Celsius	$°C^{-1}$			
heat energy, quantity of heat	Q	joule*	J	GJ MJ kJ		31
heat capacity	C	joule per kelvin	J/K*	kJ/K*		32
specific heat capacity	c	joule per kilogram kelvin	$J/(kg \cdot K)$*	$kJ/(kg \cdot K)$*		32
entropy	S	joule per kelvin	J/K*	kJ/K*		32

(1) Name of Physical Quantity	(2) Quantity Symbol	(3) Name of SI Unit	(4) SI Unit Symbol	(5) Selection of Multiples and Submultiples of SI Units	(6) Other Units Permitted for Use With SI	(7) Notes
specific entropy	s	joule per kilogram kelvin	J/(kg·K)*	kJ/(kg·K)*		32
enthalpy	H	joule	J			
Electricity and Magnetism						
electric current	I	ampere	A	kA mA μA		
electric charge	Q	coulomb*	C	kC mC		33
electric potential	V	volt	V	MV kV mV		
electric field strength	E	volt per metre	V/m	MV/m kV/m mV/m		
capacitance	C	farad	F	μF nF nanofarad pF picofarad		
resistance	R	ohm	Ω	GΩ MΩ kΩ mΩ		
Physical Chemistry and Molecular Physics						
amount of substance	n	mole*	mol	kmol mmol		34
molar mass*	M	kilogram per mole	kg/mol	g/mol		35
molar volume*	V_m	cubic metre per mole	m^3/mol	dm^3/mol cm^3/mol	L/mol	35
molar heat capacity*	C_m	joule per mole kelvin	J/(mol·K)			35
concentration*	c	mole per cubic metre	mol/m^3	kmol/m^3 mmol/m^3	mol/L	36
molality	m	mole per kilogram	mol/kg	mmol/kg		

(1) Name of Physical Quantity	(2) Quantity Symbol	(3) Name of SI Unit	(4) SI Unit Symbol	(5) Selection of Multiples and Submultiples of SI Units	(6) Other Units Permitted for Use With SI	(7) Notes
Atomic and Nuclear Physics						
mass of atom	m_a	kilogram	kg		u unified atomic mass*	37
half life	$T_{1/2}$	second	s	ms μs ns ps	min h d a	
elementary charge*	e	coulomb	C	aC attocoulomb		38
nuclear radius	R	metre	m	fm femtometre		
Nuclear Reactions and Ionizing Radiations						
reaction energy, kinetic energy	Q E_K	joule	J		eV electronovolt* keV MeV GeV	39
activity	A	becquerel*	Bq	PBq petabecquerel TBq terabecquerel GBq kBq		40
absorbed dose of ionizing radiation	D	gray*	Gy	MGy kGy mGy	eV/g	41
radiation exposure	X	coulomb per kilogram	C/kg	mC/kg	R rontgen*	42
dose equivalent	H	sievert	Sv	mSv		

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* For many of the quantities or units in the above table there are particular points with which science teachers should be familiar. Such points are identified by asterisks and appear in the following notes, which are indicated by the numbers in column 7.

Notes

1. The nautical mile (M) is used for navigational purposes; 1 M = 1852 m (exactly). The symbol M for nautical mile is not recognized universally; it is recommended.
2. The astronomical unit (AU) does not have an international symbol and varies with the language, for example, UA in French and AE in German; 1 AU = 149.597 870 Gm (gigametres).
3. The micrometre (μm) is to be used in place of the micron.
4. The nanometre (nm) is to be used to replace the ångström (Å); 1 Å = 0.1 nm (exactly).
5. The hectare (ha), similar to the acre, is used in land-area measurement in agriculture and surveying; 1 ha = 10 000 m^2 (exactly).
6. The international symbol for the litre is now recognized as either the upright, upper-case L or the upright, lower-case letter l. Since the latter may be confused with the numeral one (1), several countries, including Canada and the United States, have adopted the upper-case L.
7. The symbol for year (a) comes from the word "annum". Submultiples of the year, such as milliyear, are not used.
8. The symbol for the speed of light in vacuo is "c"; $c = 2.997\,924\,58 \times 10^8$ m/s by definition.
9. The knot (kn) is used on ships and aircraft for navigational purposes; 1 kn = 1 M/h (see note 1).
10. The symbol g is used for acceleration due to gravity. Standard acceleration due to gravity = 9.806 65 m/s^2.
11. The unit degree (°) for measuring angles, with its decimal subdivisions, is recommended for use when the radian is unsuitable, for example, 34° 15′ = 34.25° (the latter form is preferred).
12. Because a radian is an arc of a circle divided by a radius, it is dimensionless. Hence, in the application of unit analysis, rad/s = s^{-1} and $\text{rad/s}^2 = \text{s}^{-2}$. However, in some circumstances it is helpful to include "rad" in the unit symbol.
13. Periodic time is the time for one cycle, or the period, T.
14. The hertz (Hz) is often equivalent to the reciprocal second (s^{-1}), particularly for continuous waves and vibrations. For discrete repetitive items, the hertz is not used, for example, bottle caps are produced at the rate of 5 s^{-1} (read as "five per second"), not 5 Hz.
15. The revolution per second (r/s) and revolution per minute (r/min) are widely used in connection with rotating machinery.
16. The nanometre replaces the ångström (see note 4).
17. Considerable confusion exists over the use of the term *weight*. In commercial and everyday use, the term *weight* nearly always means mass. In science *weight* has primarily meant a force due to gravity. To avoid confusion, the term *weight* in science and technology should be replaced by the term *mass* or *force of gravity* depending on the application.

    The use of the verb *to weigh* meaning "to determine the mass" is acceptable. For example, "I weighed this water and found its mass to be 2 kg."

    The expressions *atomic weight* and *molecular weight* are to be replaced by *relative atomic mass* and *relative molecular mass*.

    Because of the misuse of the kilogram as a unit of force, some literature should be interpreted with caution. See note 21.

    The meanings of the terms *load*, *loading*, and *capacity* vary in different senses, including the following:

    a) The load on a drilling bit is a force, which is expressed in newtons.
    b) A wind, snow, or roof load is a pressure, which is expressed in pascals.
    c) A permissible or maximum floor load (for public information) is a mass-supporting capacity, which is expressed in kilograms per square metre.
    d) A crane or hoist load is a mass-lifting capacity, which is expressed in kilograms or metric tons.
    e) A bridge or truck load is a mass-carrying capacity, which is expressed in kilograms or metric tons.
    f) An ice load on a transmission line is a thickness, which is expressed in millimetres.
    g) An electric load is a power, which is expressed in watts.
    h) An electronic load is an impedance, which is expressed in ohms.

    When data are presented for consumer or operator use (e.g., data related to the safe working capacity of a crane or a maximum safe floor load), mass units are preferred to force units.
18. In French text of Canadian origin the term *tonne* may mean a ton of 2000 pounds. Care must be taken in the interpretation of French documents.
19. The SI unit of density is the kilogram per cubic metre (kg/m^3) and is equivalent to the gram per litre (g/L) or gram per cubic decimetre (g/dm^3), that is, 1 g/L = 1 g/dm^3 = 1 kg/m^3 (the last is preferred).

    Note: For teaching purposes in school, students should be encouraged to convert the gram per cubic centimetre (g/cm^3) or gram per millilitre (g/mL) to the kilogram per cubic metre, particularly in Senior advanced- and general-level courses.

    The term *relative density* (not abbreviated) replaces the terms *specific weight* and *specific gravity*. *Note:* The term *specific* means "per unit mass".
20. See note 17 regarding the use of the term *weight*. It is best to avoid the term in science. For instance, one should not say "My weight is 784 N," but either "My mass is 80 kg" or "The (gravity) force acting on me is 784 N."

21. The kilogram force (kgf) is obsolete and is not to be used; 1 kgf = 9.806 65 N (exactly). Also the kilopond (= 9.806 65 N) is not to be used.
22. The pascal (Pa) is the SI unit of pressure and stress, including tensile strength, modulus of elasticity, and shear stress.
23. The millibar (mbar) may continue to be used temporarily but only for international meteorological work; 1 mbar = 100 Pa.
24. Although 1 N·m is dimensionally equal to 1 J, it is customary to express torques or moments in newton metres.
25. Moment of momentum is often referred to as *angular momentum*.
26. Second moment of area is also known as the moment of inertia, particularly in structural calculations, where it is frequently expressed in millimetres to the fourth power (mm^4).
27. Stresses expressed in newtons per square millimetre (N/mm^2) are numerically equal to those expressed in megapascals (MPa); the latter is preferred.
28. Modulus of elasticity is often referred to as *Young's modulus*.
29. The joule (J) is the SI unit for all forms of energy and work. Although the watt hour (W·h) and its multiples are at present widely used as a measure of electrical energy consumption, they will eventually be replaced by the joule and its multiples. E_p and E_k are recommended as quantity symbols for potential and kinetic energy. The subscripts may be either lower- or upper-case upright symbols.
30. The kelvin (K) is often used in science, whereas the degree Celsius (°C) is used in both science and the everyday world.

    Temperature differences are stated in kelvins (K) or in degrees Celsius (°C). The "Celsius degree" (C°) is not to be used. For temperature differences, 1°C = 1 K (exactly).

    The relationship between the thermodynamic temperature (T) and the Celsius temperature (t) is $t = T - T_0$ where $T_0 = 273.15$ K by definition.
31. The SI unit for quantity of heat energy is the joule (J). The calorie (cal) is obsolete. For most references it may be assumed that 1 cal = 4.2 J or 4.19 J. The Calorie (often called the *large calorie* or *kilocalorie*) used by dietitians is equivalent to 4.2 kJ or 4.19 kJ.
32. In these units, the kelvin (K) may be replaced by the degree Celsius (°C).
33. The charge of a battery is often expressed in ampere hours (A·h). This should eventually be abandoned in favour of the kilocoulomb (kC).
34. The amount of substance of a given system is the number of elementary entities (e.g., atoms, molecules, or ions) in the system divided by Avogadro's constant (N_A), which is the number of ^{12}C atoms in 0.012 kg of ^{12}C; $N_A = 6.022\ 136\ 7 \times 10^{23}$ mol^{-1}.
35. In the naming of physical quantities, *molar* means "per unit amount of substance".
36. The obsolete term for concentration, *molarity*, should not be used; the term is simply *concentration*. The terms *equivalent weight* and *equivalent* are also obsolete and should not be used.

    Many other ratios of physical quantities have been termed *concentration* in the past and may be found in reference books for some time to come. The recommended terminology for various ratios is as follows:

Concentration	(c)	in mol/m^3	
Molality	(m)	in mol/kg	
Specific volume	(v)	in m^3/kg	
Molar mass	(M)	in kg/mol	
Molar volume	(V_m)	in m^3/mol	
Mass concentration	(ρ_B)	in kg/m^3	(This is not equivalent to density but has the same dimensions.)

    If a comparison is made between substance B and substance A, where B is in A and the same unit is used to measure both substances, then the ratio is a dimensionless fraction. For example, if two masses are compared (25 g of salt in 1000 g of water), the dimensionless quantity is referred to as the mass fraction. The following names are recommended for such fractions:

Mole fraction	(x_B)	in mol/mol	(or mmol/mmol, etc.)
Volume fraction	(φ_B)	in m^3/m^3	(or mL/mL, etc.)
Mass fraction	(w_B)	in kg/kg	(or g/g, etc.)

37. 1 u = $1.660\ 565\ 5 \times 10^{-27}$ kg
38. The elementary charge (e) = $1.602\ 177\ 33 \times 10^{-19}$ C = 0.160 217 733 aC
39. 1 eV = 0.160 217 733 aJ
40. The becquerel (Bq) is the activity of radionuclides that is equal to one per second. Activity in becquerels is a measure of radioactivity. For example, Cobalt 60, used in therapy, has an activity of about 60 TBq. Such activity is not a continuous phenomenon as in vibrations or waves but is discrete and is therefore not stated in hertz. See note 14. The former unit of activity, the curie (Ci), is obsolete and has been replaced by the becquerel (Bq); 1 Ci = 37 GBq.
41. The gray (Gy) is the absorbed dose that is equal to one joule per kilogram. The former unit of absorbed dose, the rad, is obsolete and has been replaced by the gray. 1 rad = 10 mGy. *Note:* In SI "rad" is the symbol for radian.
42. The rontgen (R) is a special unit employed to express exposure to X or γ radiation. This definition applies only to ionization in air. The rontgen is permitted for use with SI for a limited time; 1 R = 2.58×10^{-4} C/kg.

Table 2: SI Prefixes

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Table 3: Some Units That Are Not Permitted for Use With SI

Quantity	Name	Symbol	Definition
length	ångström	Å	1 Å = 0.1 nm
	micron	μ	1 μ = 1 μm
force	kilogram force	kgf	1 kgf = 9.806 65 N
	dyne	dyn	1 dyn = 10 μN
pressure	torr	Torr	$1\ \text{Torr} = \frac{101\,325}{760}\ \text{Pa}$
	millimetre of mercury	mm Hg	1 mm Hg = 133.322 Pa
	bar*	bar	1 bar = 100 kPa
	standard atmosphere	atm	1 atm = 101.325 kPa
energy	calorie	cal	1 cal = 4.1868 J
	erg	erg	1 erg = 0.1 μJ
activity	curie	Ci	1 Ci = 37 GBq

*The millibar is permitted for a limited time.

Table 4: Values of Some Physical Constants

Quantity	Symbol	Value
Avogadro's constant	N_A	$6.022\,136\,7 \times 10^{23}$/mol
Bohr (first electron orbit) radius	a_0	52.917 724 9 pm
Coulomb's constant	k	9.0×10^{9} N·m²/C
electron radius	r_e	2.817 940 92 fm
elementary charge	e	0.160 217 733 aC
earth: equatorial radius	–	6.378 Mm
polar radius	–	6.357 Mm
mean orbital speed	–	29.770 km/s
mass	–	5.983×10^{24} kg
volume	–	1.087×10^{21} m³
gravitational constant	G	$6.672\,59 \times 10^{-11}$ N·m²/kg²
mass of electron	m_e	$0.910\,939 \times 10^{-30}$ kg
mass of neutron	m_n	$1.674\,929 \times 10^{-27}$ kg
mass of proton	m_p	$1.672\,623 \times 10^{-27}$ kg
molar volume of gas at 273.15 K, 101.325 kPa	V_m	0.022 414 10 m³/mol
Planck's constant	h	6.626 075 5 10^{-34} J·s
speed of sound in air, sea level	v	331.29 m/s
standard acceleration due to gravity	g	9.806 65 m/s²
atomic mass unit	u	$1.660\,565\,5 \times 10^{-27}$ kg
velocity of light in vacuo	c	$2.997\,924\,58 \times 10^{8}$ m/s

Appendix C

Metric Editorial Practice

This appendix presents many points regarding metric editorial practice that are set forth in the *Canadian Metric Practice Guide* (CAN3-Z234.1-79) and the *Metric Editorial Handbook* (Z372-1980). These two documents should be in each secondary school library resource centre. They may be purchased from the Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario M9W 1R3. The number associated with each rule may be used for the rapid identification of a particular point.

1. Some Fundamental Rules of Style

001
All SI units have symbols; abbreviations shall not be used:

kg (for kilogram; not kilo)
r/s (for revolution per second; not r.p.s.)

002
Symbols for units of measure are printed in upright type:

m (metre)	s (second)	J (joule)
Hz (hertz)	m^2 (square metre)	km/h (kilometre per hour)

003
The first letter of symbols for units named after scientists are capitalized:

N (newton) Pa (pascal) °C (degree Celsius)

004
Symbols for units not named after scientists are printed in lower case:

s (second) kg (kilogram) rad (radian)

Note that the exception to this rule is L for litre because the lowercase letter "l" can be confused with the numeral one (1). Metric prefixes, such as *mega-* and *giga-*, that are larger than *kilo-*, are capitalized:

GJ (gigajoule) Tm (terametre) MW (megawatt)

005
Symbols remain unaltered in the plural:

cm (for centimetre or centimetres)

006
Symbols are written without a period after them except at the end of a sentence.

007
Symbols are placed so that there is a space between the last digit of a numeral and the first letter of the symbol. If the symbol does not start with a letter, the space is omitted:

3 s	200 mL	3×10^8 m/s
41.2 m^3	37°C	45°

008
In technical writing, physical quantities are shown by means of a numeral and a unit symbol:

9 cm (not 9 centimetres or nine cm)

009
If it is expected that the symbol may be unknown to the reader, the name of the unit may be included in parentheses:

37 TBq (terabecquerels)

010
In prose, if the number is spelled out, the unit is also to be spelled out:

She skated about three kilometres.

011
When no numeral is involved, the unit is spelled out:

Joules are to replace calories.

012
In text, a symbol should not be used to start a sentence.

013
Unit names may be spelled differently in different languages, but unit symbols are international and are the same in all languages, including English and French:

kg (for kilogram in English, kilogramme in French, chilogramma in Italian, and quilogramma in Portuguese)

014
Unit names are spelled out in lower-case letters:

metre kilowatt newton
joule ampere hertz

Note that the one exception is *degree Celsius*. If a unit name occurs at the beginning of a sentence, it is naturally capitalized.

015
Symbols for area and volume are read as "square unit" and "cubic unit"; other exponential symbols are read as "unit squared" and "unit cubed":

m^2 (square metre)
cm^3 (cubic centimetre)
m/s^2 (metre per second squared)

016
Units involving higher powers or negative powers should be expressed as "unit to the power x", "unit to the xth power", or "unit to the power negative x".

017
Unit names and symbols should not be mixed:

$kg \cdot m/s^2$ (not $kg \cdot m/second^2$)

018
Quantity symbols are printed in sloping type:

m (mass) t (time) l (length)
F (force) p (pressure) P (power)

019
When it is necessary to distinguish between variations of a quantity, the quantity name or symbol is modified, not the unit or unit symbol:

$I_{dc} = 15$ A (a direct current of 15 A; $I = 15\ A_{dc}$ would be incorrect)

020
Where space is limited, as on a nameplate, the modifier may be included in parentheses after the unit:

15 A (dc) 110 V (ac) 30 kPa (gauge)

021
Prefix symbols are attached directly to SI unit symbols to form a single new symbol. The entire new symbol can have an exponent:

cm^2 – this means $(cm)^2$

022
Compound units are represented by compound symbols, which can be multiplied, divided, and raised to a power:

$N \cdot m$ km/h mm^2
$kg \cdot m/s^2$ $J/(kg \cdot °C)$ $m \cdot s^{-2}$

023
Compound prefixes are not used:

Gg (gigagram, not Mkg, megakilogram).
fm (femtometre, not $\mu\mu$m for micro-micrometre)

024
No more than one unit shall be used to designate a measurement:

2.345 m (not 2 m 34 cm 5 mm)

Note that plane angles (in degrees, minutes, and seconds) and time units (e.g., in hours and minutes) are exceptions that are permitted.

025
When a quantity is stated, the unit chosen should be such that the numerical part falls between 0.1 and 1000:

35 kJ (preferred to 35 000 J)
2.8 mm (preferred to 0.0028 m)
42 nm (can also be written as 4.2×10^{-8} m)

Note that values may fall outside the suggested numerical range when similar quantities are compared, quantities are expressed in standard form, or quantities are converted to coherent SI units.

026
Not more than one prefix should be used in a compound unit, and the prefix should be in the numerator:

kV/m (not V/mm)

Note that the exception to this rule exists when the kilogram (kg), a base unit, is included in the denominator:

mol/kg (rather than mmol/g)

027
The multiplication of symbols shall be shown by a dot at mid-letter height when printed, as in N·m, or on the line when typed, as in N.m:

$\text{kg}\cdot\text{m}\cdot\text{s}^{-1}$ (kilogram metre per second for momentum)
km·t (kilometre tonnes for freight transport)

028
The division of symbols shall be indicated by a solidus, a negative exponent, or a horizontal line:

m/s $\quad$ $\text{m}\cdot\text{s}^{-1}$ $\quad$ $\frac{\text{m}}{\text{s}}$

Note that the solidus is preferred for computers.

029
The solidus shall not be repeated in a symbol unless parentheses are used to identify whether division is in the numerator or denominator:

(km/h)/s, but not km/h/s
J/(kg·K), but not J/kg/K

030
When names of compound units are spelled out in English, multiplication is indicated simply by a space, not a hyphen, and division is shown by the word *per*, not the solidus (/):

newton metre (not newton-metre)
metre per second (not metre/second)

Note that multiplied units when spelled out in French *are* hyphenated (see 050).

2. Abbreviations

031
In the expression of SI measurements there are no abbreviations, only upright symbols for units and prefixes:

cm^3 (not c.c. or cc or cu.cm.)
km/h (not k.p.h. or kph)
r/min (not r.p.m. or rpm)

032
Physical quantities are represented by sloping symbols, not abbreviations:

T or t (not temp for temperature)
E_p and E_k (preferred to P.E. and K.E. for potential and kinetic energy)

033
In science, abbreviations do occur and often differ from one language to another:

ac (alternating current); dc (direct current)
kn (knot); AU (astronomical unit)
lim (limit); log (logarithm); exp (exponential)
sin (sine); cos (cosine); tan (tangent)

034
Slang terms for units should not be printed despite the tendency to use them in conversation:

kg or kilogram (not kilo or kilos)
A or ampere (not amp or amps)

035
Chemical symbols must not be mixed with metric unit symbols:

80 kg/ha for distribution of nitrogen (not 80 kg N/ha – here the N would represent a *newton* of force)

3. Adjectival Use of Units

036
A quantity may be expressed in an adjectival sense, that is, where a numeral and a unit form a hyphenated compound adjective:

100-mm nail $\quad$ twelve-volt battery
200-mL flask $\quad$ sixty-minute timer

037
In technical text, the number and unit should be expressed in numeric and symbolic form. The hyphen should be used if its absence would cause ambiguity.

60 W bulb
2-L flasks
two 1-L flasks

038
The hyphen should not be used when the symbol does not begin with a letter:

a 45° angle $\quad$ two 100°C thermometers

039
The hyphen need not be used when more than one measure is stated:

a 30 cm x 40 cm picture or a 30 × 40 cm picture

040
When terms are spelled out in prose, a hyphen is used except in cases where the number or unit consists of several words:

our two hundred and fifty hectare farm
the fifty kilometre per hour speed limit

041
The name of a unit may be used as an adjective. If so, it is spelled out; the symbol is not used:

centimetre-cubes (not cm-cubes)
litre-bottles (not L-bottles)

4. Algebraic Expressions

042
Quantity symbols and algebraic symbols in formulas and equations are printed in sloping letters, while unit symbols and numerals are printed in upright type:

2π rad
$(2a - b)$ cm
$V = lwh$
$V = (x\ \mathrm{cm})\,[(x + y)\ \mathrm{cm}]\,[(x - y)\ \mathrm{cm}]$
$\quad = (x^3 - xy^2)\ \mathrm{cm}^3$
$V = 3.4\ \mathrm{m} \times 50\ \mathrm{cm} \times 10\ \mathrm{mm}$
$\quad = 34\ \mathrm{dm} \times 5\ \mathrm{dm} \times 0.1\ \mathrm{dm}$
$\quad = 17\ \mathrm{dm}^3$ or $17\ \mathrm{L}$
$F = ma$
$25.2\ \mathrm{N} = m \times 3.0\ \mathrm{m/s}^2 \quad \therefore m = 8.4\ \mathrm{kg}$

043
Trigonometric expressions should include unit symbols, but normally do not because it is assumed that they are understood:

sin 60 (assumed to mean "sin 60°")
tan $\pi/4$ (assumed to mean "tan $(\pi/4)$ rad")

5. Calendar Dates

(See also subsection 25, "Time of Day".)

044
Calendar dates are not part of SI, but since they may be used in science, they are mentioned here for optional adoption. They may be expressed in either the alpha-numeric way (e.g., March 15, 1989) or the all-numeric way (e.g., 1989 03 15 or simply 89 03 15).

045
The all-numeric form may be useful for office memoranda, chronological files, and the recording of observations over a prolonged period. The order of year, month, and day is always maintained. The century may be omitted. The year is indicated by four or two digits, the month by two digits, and the day by two digits:

1988 11 23 or 88 11 23 (for November 23, 1988)
1989 02 08 or 89 02 08 (for February 8, 1989)

Note that handwritten dates should be hyphenated (e.g., 89-02-08); typed or printed ones need not be. The separators, the spaces or hyphens, are not essential and may be omitted as is often the case in computer printouts (e.g., 19890208).

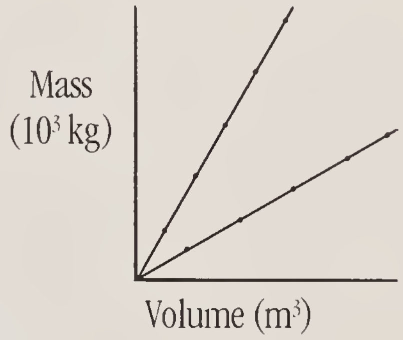
046
The date and time of day may be combined in the all-numeric format, in which the separators between year, month, day, and hour must be hyphens and the time-of-day separators must be colons:

1987-06-28-15:30 (for 3:30 p.m. on June 28, 1987)
1987-12-31-23:59:59 (for 1 s before the end of 1987)

6. Column Headings and Axes of Graphs

047
The labelling of column headings and the axes of graphs should be consistent in any one table or graph. The name of the physical quantity and the unit of measure shall be given. The unit may be spelled out or shown (usually in parentheses on axes of graphs) as a symbol:

Mass (kg)
Mass (kilograms)
Mass (10^5 kg)
Time (years)
Temperature (°C)
Temperature in degrees Celsius
Population density (people/ha)
Population density (10^3 people/km^2)



048
In a column heading, where the unit is usually placed under the name of the physical quantity, the parentheses may be omitted:

Pressure kPa	**Pressure (kPa)**	**Pressure kilopascals**	**Pressure 10^2 kPa**
1250	1250	1250	12.5
980	980	980	9.8

7. Compound Units

049

A compound unit is a combination of two or more units or an exponential power of a unit:

newton metre or N·m
ampere second or A·s
joule per kilogram degree Celsius or J/(kg·°C)
cubic centimetre or cm^3
reciprocal second or s^{-1}

050

Hyphens, dots, multiplication signs, oblique strokes, brackets, and exponents are not used in the name of a compound unit:

pascal second (not pascal-second, pascal·second, or pascal × second)
metre per second (not metre/second)
metre per second squared (not metre per second^2)

Note that in the French language pascal-seconde is hyphenated (see 030).

051

Only one prefix should be used in a compound unit, preferably attached to the first unit or to a unit in the numerator:

millinewton metre (rather than newton millimetre)
kilometre per second (not metre per millisecond)

Note that the kilogram, rather than the gram, is the preferred unit of mass, since it is an SI base unit. If "kg" appears in a compound symbol, another prefixed symbol is permissible:

500 kJ/kg or 5.00×10^5 J/kg (not 500 J/g)

052

Particular practices within an industry may require a prefix in the denominator for convenience or comparison:

150 kg/km (for mass per unit length of a cable)
33 t/ha (for the yield of corn crop)
40 rows/dm (for the linear density of the rows in a carpet)

053

In unit symbols multiplication is indicated by a dot (see 027) and division by an oblique stroke or solidus (see 028). Denominators containing two or more terms are enclosed in parentheses:

35 N·m (not 35 Nm, 35 N × m, or 35 N-m)
V·m·s (for volt metre second; not Vm·s, V·ms, or Vms)
Pa·m^3 or kPa·L (the latter is acceptable for practical work in pressure-volume relationships)
J/(kg·°C), but not J/kg·°C
L/(100 km), but not L/100 km

8. Conversion Factors

(See also subsection 23, "Rounding Converted Values".)

054

Conversion factors between metric and imperial units, if given, should appear in an appendix rather than as part of the text, and then only if they are considered necessary or to facilitate the understanding of measurement practice in everyday life. As a rule, such factors are needed only when imperial usage in a sector remains as the predominant practice. If only a few conversion factors are needed, they may be shown in footnotes.

055

Qualitative comparisons between imperial and metric may be included in a text, but only if needed:

A kilogram is a little more than two pounds.
A fluid ounce is about 30 mL.

9. Decimal Marker

(See also subsection 12, "Fractions", and subsection 17, "Numbers".)

056

The point or comma may be chosen as the decimal marker. In Canada, French-language publications generally show the comma, and English-language publications, the point. If there is no particular reason for selection, the point should be used.

057

In a bilingual text both markers may be used, the point for the English and the comma for the French. However, tables of values need not be printed twice, so long as an understanding can be reached as to which marker will serve in place of the other. Consistency should be maintained throughout a text.

058

The space to the left of a decimal marker must be occupied by a zero if no other digit is there:

0.37 kg (not .37 kg)

059

If the decimal point is used, a series of numbers should be punctuated with the comma. If the decimal comma is used, the series should be punctuated with the semicolon:

0.2, 1.4, 2.6, 3.8, ...
0,2; 1,4; 2,6; 3,8; ...
$(x, y) = (1.8, -3.9)$
$(x; y) = (1{,}8; -3{,}9)$

060

The decimal marker is printed level with the base of the numerals beside it. The raised dot is not used as a decimal marker nor as a multiplier between numerals:

3.5 or 3,5 (for three and a half, but never as 3·5)
3×5 (for multiplication, never 3·5)

061

The comma is not to be used as a triad separator, that is, to separate digits in a large number into groups of three digits. A space is to be used to separate the triads:

84 500 (not 84,500 to mean "eighty-four thousand five hundred" since 84,500 could mean "eighty-four decimal five")
See also subsection 17, "Numbers", for further examples.

10. Division

(See also subsection 11, "Exponents", and subsection 18, "Per".)

062

Division may be expressed by means of:

- an oblique stroke or solidus (/) with unit symbols, but not with names of units;
- a horizontal bar with unit symbols and with names of units;
- a negative exponent with unit symbols, but not with names of units;
- the word *per* with names of units, but not with unit symbols:

m/s (but not metre/second)

$\frac{\mathrm{m}}{\mathrm{s}}$ $\frac{\mathrm{J}}{\mathrm{kg \cdot {}^{\circ}C}}$ $\frac{\text{kilogram}}{\text{cubic metre}}$

$\mathrm{m \cdot s^{-1}}$ $\mathrm{V \cdot A^{-1}}$ $\mathrm{{}^{\circ}C^{-1}}$

Note that the form containing the horizontal bar is now of less importance because of the computer use of the oblique stroke.

063

The division sign (÷) is generally used in science only for the purpose of explaining a mathematical operation.

064

Except for the kilogram (the SI base unit of mass), no prefix should normally appear in the denominator:

$2.5\ \mathrm{kg/m^2}$ (not $250\ \mathrm{mg/cm^2}$)
See also 026 to 030.

11. Exponents

065

Exponents shall consist of superscript numerals immediately after the unit symbol:

$\mathrm{mm^3}$ $\mathrm{s^{-1}}$ $3 \times 10^8\ \mathrm{m \cdot s^{-1}}$
$\mathrm{kg \cdot m^2/s^2}$ $\mathrm{m \cdot s^{-2}}$ $2.24 \times 10^{-2}\ \mathrm{m^3/mol}$

066

When a numeral bears an exponent, the space between the numeral and the symbol is maintained:

$3 \times 10^8\ \mathrm{m/s}$ (not $3 \times 10^8\mathrm{m/s}$)

067

The exponent following a prefixed symbol applies to both the prefix and the unit:

$1\ \mathrm{cm^3} = 1(\mathrm{cm})^3 = 1(10^{-2}\ \mathrm{m})^3 = 10^{-6}\ \mathrm{m^3}$

068

When spelled out, a unit and its exponent shall be spelled out together:

square centimetre (not centimetre^2)
metre per second squared
millimetre to the power four *or* millimetre to the fourth power
reciprocal millisecond *or* millisecond to the negative one

12. Fractions

069

Fractions may be expressed in the form of a decimal or as a numerator over a denominator. The first method is much to be preferred for stating measurements. The second method should be used when only the simplest fractions (e.g., 1/2, 1/3, 3/4) are involved:

about 0.25 cm in diameter (or about 2.5 mm)
about 1/4 cm in diameter
half life is 3.5 h (avoid use of 3-1/2 h)
a pressure of 0.75 MPa (rather than 3/4 MPa)

13. Hybrid Terms

070

A hybrid term is one containing an SI unit and a non-SI term or item:

30 trees/ha
20 kg/bag
50 words/min
24 L/case
cents per kilogram
150 mL/tube
3200 passenger·km (for bus transportation)
25 worker·d/m (worker days per metre, e.g., for rate of construction of highrise buildings)

071

There must be at least one symbol adjacent to the dot or oblique stroke in hybrid symbols. Neither the dot nor the stroke is used between two fully spelled words:

20 strokes/min or 20 strokes per minute (not 20 strokes/minute to denote a rowing rate)
8 stitches/cm (sewing)
800 turns/m (yarn twist or turns of wire on an electromagnet)
30 rows/dm (carpet)
3 cm/century or 3 cm/(100 a) (erosion rate)
8.49 $/kg (cost per unit mass)
97 ¢/L (cost per unit volume)
25 000 $/d or 25 k$/d (company expenditure per unit time)

072

Prefix symbols are not to be used alone:

$29 per 1000 (not $29/k or $29 per k)
an annual budget of $3 million (not $3M)

14. Hyphens

(See also subsection 3, "Adjectival Use of Units".)

073

Hyphens are used in adjectival forms to avoid ambiguity and nowhere else for stating physical quantities. They are also used in stating all-numeric calendar dates, which are not a part of the SI. In adjectival forms, the hyphen may be omitted if the meaning is very clear:

30-cm zipper
two 1.5-V cells
one hundred and twenty 100-W bulbs or ten dozen 100-W bulbs (not 120 100 W bulbs, because this is ambiguous)
2-L bottles (bottles each having a capacity of 2 L)
two 1-L bottles (a couple of bottles each having a 1-L capacity, but not 2 L bottles, because this is ambiguous)

15. Multiple Descriptors

074

In a multiple descriptor, two or more quantities are used to describe a single item:

a 125 to 135°C oven
a 15 by 20 m house
a 110 V, 15 A appliance

075

A range of values may be used (indicated by a dash or "to"):

a 110-120 V connector
a 30 to 40 m rope

076

A product of values may be used (indicated by " × " or "by"):

a 6 × 13 × 22 cm box (or a box 6 × 13 × 22 cm)
a 6 by 13 by 22 cm box

Note that if the unit is the same for all values, it need be given only once, although it may be repeated (e.g., 6 cm by 13 cm by 22 cm box) if desired. If the units differ, they must naturally be included (e.g., 10 cm x 30 cm x 1.2 m carton).

077

A set of measurements, separated by commas, may be used:

a 40-cm, 84-cm shirt
a 300-L, 200-W refrigerator
a 600-A, 220-V cable

Note that hyphens may be omitted (e.g., 40 cm, 84 cm shirt) provided that there is no ambiguity.

16. Multiplication

078

The product of two or more unit symbols is indicated by a raised dot between them. The dot may be on the line in typewritten work or in computer printouts:

N·m (for newton metre, a unit of torque)
km·t (for kilometre tonnes of railway freight movement)
V·A
kW·h
$(\mathrm{m}^3/\mathrm{s})\cdot\mathrm{d}$
W/(m·°C)
$\mathrm{mol}\cdot\mathrm{m}^{-3}$
$\mathrm{kg}\cdot\mathrm{m}^2\cdot\mathrm{s}$

Note that in a hybrid term (see subsection 13, "Hybrid Terms") the dot is placed between a word and a symbol (see 070).

079

The multiplier dot may be used with algebraic symbols, but not between numerals or between a numeral and a symbol:

3.1×8.2 or $(3.1)(8.2)$, but not $3.1 \cdot 8.2$
$1.9y^2$, but not $1.9 \cdot y^2$

See also 027 and 030, as well as 050 and 053.

17. Numbers

080

To improve readability, long numbers are arranged in groups of three digits (triads) on either side of the decimal marker. Adjacent triads are separated by spaces:

602 391.28
31.627 45
52 329.816 3

081

Numbers of four digits (on either side of the decimal marker) should be separated into triads only when they are grouped with others of more than four digits:

Group A	*Group B*	*Group C*
7621.98	9 002	4.816 4
382.41	12 320	3.922 81
8000.29	58 916	0.318 9
1731.11	1 132	11.123 48

082

The separation of digits into triads is not appropriate in all instances:

Identification numbers: B123-45678-01234
Telephone numbers: (416) 123-4567
Dates and times: 1986 12 25 and 09:30
Arithmetic calculation:

$$\begin{array}{r} 12345679 \\ \underline{36} \\ 74074074 \\ \underline{37037037} \\ \underline{\underline{444444444}} \end{array}$$

The answer would be shown separately as 444 444 444.

083

Units and numerals are written in symbolic and numeric form in scientific and technical text (see also 008):

20 kg (not twenty kg or 20 kilograms)

Note that in newspapers, magazines, and books of general interest the numeral is often followed by a fully spelled-out unit, as in 20 kilograms. This form is not favoured in science. (See also 009.)

084

Terms such as *billion* and *trillion* are ambiguous because they have different meanings in different countries. They should be avoided and replaced with:

- expressions such as *thousand million* and *million million*;
- SI prefixes – giga, tera, exa, and peta – adjoined to appropriate units;
- powers of ten such as 10^9, 10^{12}, 10^{15}:

Distance from earth to sun
= 150 Gm (not 150 billion metres)
= 150×10^9 m
= 150 million kilometres (this form is appropriate in a magazine)

18. Per

(See also subsection 10, "Division".)

085

To indicate division in the name of a unit, the word *per* is inserted between the fully spelled-out units. The solidus (/) is inserted between the corresponding symbols when the unit is written in symbolic form:

kilometre per hour or km/h (not kilometre/hour or km per h)

086

Per should not appear twice in an expression:

"an annual cost of thirty dollars per square metre" (preferred to "thirty dollars per square metre per annum")

087

Expressions such as *per diem*, *per annum*, *per capita*, and *per cent* are acceptable provided that the *per* is not replaced with the solidus. In technical work, the symbol "%" is preferred over "per cent" when associated with numerals:

In a year we consume 82 kg of potatoes per capita.
95% (without a space between the numeral and the symbol)

19. Plurals

088

An *s* is added to pluralize the names of all SI units of measure except *hertz*, *lux*, and *siemens*. Unit symbols remain unchanged in the plural:

The frequency increased by anywhere between one and three hertz.
My temperature dropped a couple of degrees Celsius.
Use henrys to indicate the amount of electrical inductance.
Volume flow rate is stated in cubic metres per second.

20. Prefixes

089

Prefixes are chosen, as a rule, for numeric convenience so that the numeric value of a measurement is neither too large nor too small, but somewhere between 0.1 and 1000. There may be constraints that dictate the use of other prefixes. (See 025.)

090

In scientific work prefixes representing 10 raised to a power that is a multiple of three are preferred, that is, kilo ($\times\ 10^3$), mega ($\times\ 10^6$), giga ($\times\ 10^9$), and so on, or milli ($\times\ 10^{-3}$), micro ($\times\ 10^{-6}$), nano ($\times\ 10^{-9}$), and so on:

3.6 Mm or possibly 3600 km (rather than 36×10^5 m)
Distance between the sun and Mars = 228 Gm
0.3 μm or 300 nm (rather than 0.0003 mm)

091

Hecto ($\times\ 10^2$), deca ($\times\ 10$), deci ($\times\ 10^{-1}$), and centi ($\times\ 10^{-2}$) are accepted for some linear, area, and volume measurements:

Centimetres are used for body, clothing, and textile measurements.
Cubic centimetres are used to express the volumes of small blocks.
Hectares are often used for farm areas.
Decimetres are used to express line densities in carpets (e.g., 32 rows/dm).

092

No prefix is to be added (a) to any symbol that does not start with a letter, such as the symbols for degree Celsius and the degree, minute, and second of an angle; or (b) to units of time other than the second:

2000°C (not 2 k°C)
300 h (not 3 hh)

Note that 2 kK (kilokelvins) is acceptable.

093

Only multiple prefixes may be added to the tonne (t). Submultiples shall not be used:

kilotonne (kt) and megatonne (Mt), but not millitonne

Note that reference is not made to "kilometric ton", "megametric ton", and so on.

21. Pronunciation

094

The following pronunciations are recommended by the Canadian Standards Association. The accented syllable is italicized:

*ex*a	with the "a" as in "about"
*gig*a	with the "gig" as in "giggle"
*kil*o	with the "kil" as in "kill"
*nan*o	with the "nan" rhyming with "can"
*pic*o	with the word rhyming with "pekoe" as in "pekoe tea"
can*dell*a	with the accent on the "dell"
*hec*tare	with the "tare" rhyming with "care"
joule	with the word rhyming with "pool"
*pas*cal	with the word rhyming with "rascal"
*meg*ohm	with the accent on "meg"

095

"*Kil*ometre" has the accent on the first syllable.

Note that many people put the accent or stress on the second syllable and are inconsistent because they do not do so with other units having kilo as a prefix (e.g., *kil*olitre, *kil*ogram, *kil*owatt). The accent on the second syllable is appropriate when talking about measuring devices such as ther*mom*eter, ba*rom*eter, speed*om*eter, mic*rom*eter, and *odom*eter. Note also that metric units, such as *kil*ometre, *kil*olitre, and *mic*rometre, end with the "re" spelling, whereas words denoting measuring instruments, such as those mentioned above, end with the "er" spelling.

22. Ratios

096

Where similar quantities are compared, ratios without metric units may be used:

slope = rise/run = 5 cm/m = 5/100 = 1:20 = 5% = 0.05

$$\text{relative density of copper} = \frac{\text{density of copper}}{\text{density of water}} = 8.93$$

$$\text{coefficient of friction} = \frac{\text{applied force}}{\text{normal force}} = \frac{3\ \text{N}}{10\ \text{N}} = 0.3$$

solubility = 58 g/(100 g) = 0.58 by mass = 58% by mass
map ratio = 1:100 000 (meaning 1 cm represents 1 km)
parts per million (ppm) = 20 cm^3 of water vapour in every 1 m^3 of air
= 20 ppm by volume
parts per million (ppm) = 45 mg of dust in each 1 kg of air
= 45 ppm by mass

097
Parts per million should only be given where both units in the numerator and denominator are identical, that is, in $cm^3/(10^6\ cm^3)$, in $mg/(10^6\ mg)$, and so on, and then the words *by volume* or *by mass* must be added.

If there are 5 mL of water vapour to every cubic metre of air, the vapour content = 5 ppm by volume.
If there are 5 g of water vapour to every cubic metre of air, the vapour content = 5 g/m^3 (not 5 ppm). Here, 5 g/m^3 is called the *mass concentration*. See Appendix B.

098
Parts per billion (ppb) should be avoided because of the ambiguous use of *billion*. (See also 084.)

23. Rounding Converted Values

099
The precision of a converted value (from imperial to metric) should reflect the precision implied in the original measurement or statement. This can often be indicated by using the same number of significant digits or by using a unit of approximately the same size as the original unit.

32 inches should be changed to 81 cm (not 81.28 cm).
32.0 inches should be converted to 81.3 cm.
32.00 inches should be converted to 81.28 cm.
A height of 5 ft 11 in should be called 180 cm (not 1.8 m or 180.34 cm).
100 acres converts to 40 ha (not 40.47 ha).

100
Non-critical values should be rounded to a convenient number within roughly 5 per cent of the original and modified by a word such as *about*, *roughly*, or *approximately*:

5.0 ounces is about 140 g (not 141.75 g).
200 Calories is roughly 840 kJ.
100 pounds is approximately 45 kg.
70°F = 20°C (approx.)

24. Spelling

101
The spelling of the units and prefixes shown in the left-hand column below is to be adopted in Ontario schools. The right-hand column shows variations used in some other English-speaking countries:

Canadian Spelling	*Other Spelling* (not acceptable in Canada)
deca	deka
gram	gramme
litre	liter
metre	meter (See 102 below.)
kilohm	kiloohm (See 103.)
megampere	megaampere (See 103.)
megohm	megaohm (See 104.)
gigohm	gigaohm (See 104.)
metric ton	metric tonne
tonne	metric tonne

102
Meter is the Canadian spelling for a measuring device (e.g., micrometer, barometer, thermometer). *Metre* is the spelling reserved for the SI unit of length, and the word is included in such units as micrometre, centimetre, and kilometre. (See also 095.)

103
When the final letter of the prefix and the first letter of the unit are the same vowel, the former is omitted in Canadian spelling:

kilohm, megampere

104
When the final letter of the prefix and the first letter of the unit are different vowels, both are normally retained:

milliampere, picoampere, teraohm

Note that *megohm* and *gigohm* are exceptions to this rule in Canada.

25. Time of Day

105
An instant of time in the day is expressed in a different way from that used to state a time interval. The former is a particular time in the day (e.g., 9:30 a.m.); it includes a colon and omits any units of time (they are understood). The latter lasts from one instant of time to another, such as from 9:30 a.m. to 11:45 a.m., that is, a time interval of 2 h 15 min, which does not include a colon but does include time units:

> The time is "half past six in the morning" ("6:30 a.m.", or "06:30").
> The time taken for the drive to Ottawa was 6 h 30 min (or 6.5 h).

106
The twenty-four-hour system of timekeeping is not part of the metric system, but if used, the time units shall be omitted, and the numbers shall be separated by colons:

> 18:45 or 6:45 p.m. (not 18h45, 1845 h, 1845, or 18 h 45 min)

107
The time of day can be expressed by (a) the all-numeric form (e.g., 08:45 and 18:30) or (b) the alpha-numeric form (e.g., 8:45 a.m. and 6:30 p.m.). In all-numeric times, there are four digits, two representing the hour and two representing the minutes after the hour. For greater precision, two additional digits may be added to represent the seconds:

> 00:15 is 15 min after midnight (i.e., 12:15 a.m.).
> 12:00 is noon.
> 16:30 is the same as 4:30 p.m.
> 23:58 is 2 min before midnight (i.e., 11:58 p.m.).
> The agenda of a meeting might show that it starts at 13:30 and ends at 16:15.

108
When the time of day is expressed very precisely in the all-numeric form, hours, minutes, and seconds are separated by colons:

> The flash of lightning occurred at 06:02:43.

Note that all-numeric dates may include all-numeric times, as indicated in 046.

26. Time Units

109
It is not desirable or necessary to express every time interval in terms of the SI base unit of time, the second, unless such an interval is less than a minute or two:

> Light travels 300 m in 1 s.
> The computer calculation took 5 ns (nanoseconds).
> The period of the pendulum is 1.2 s.
> The ball travelled down the 3.8-m ramp in 42.6 s.

110
For periods of time that are longer than 60 s, the minute, hour, day, and year are permitted for use with the SI and are preferred to units such as the kilosecond and higher multiples of the second.

> 60 years old (not 1.9 Gs)
> ... bake in kiln for 5 h (not 1.9 ks)
> ... 30 d for cement to cure (not 4.3 weeks)

111
In science, the symbols "min", "h", "d", and "a" shall be used when such time units are preceded by numerals and express scientific data. However, in general contexts or in adjectival expressions, they should be spelled out in full:

> He was ill for 14 days.
> ... my 8-year-old child (not my 8-a-old child)
> She married 31 years ago (not 31 a ago).

Note that care should be taken when "a" is used as the symbol for *year* or *annum* to prevent it from being misinterpreted as the indefinite article.

112
Symbols must be used for time units that are part of an expression involving other SI unit symbols. If this is not desirable, the time units can be expressed in words elsewhere in the statement:

> The mass flow rate was 35 kg/min.
> The energy absorbed is 8 MJ/d.
> The glacial rate of flow was about 2 m/a. (The annual movement of the glacier was about 2 m.)

113
Time intervals (in contrast to the time of day) may be expressed with the use of more than one unit (this is counter to normal practice – see 024):

> Flying time is 4 h 50 min (rather than 4.83 h, which is not incorrect, but is impractical).

114
There is no international symbol for week or for month. It is advisable to spell these units out in full:

gestation period: 5 weeks
shelf life: 3 months

27. Unit Symbols With Numerals

115
The normal method for stating a measured quantity is to express the measurement using the numeric and symbolic forms:

200 kg	50 mL	305 cm^3
110 V	9.8 m/s^2	0.32 $kg \cdot m \cdot s^{-1}$

116
Where numerals are not customarily shown, but the numbers are spelled out, as may be the case in prose text, the unit shall also be spelled out:

The area is twelve square metres (not twelve m^2).
She lost a few kilograms (not a few kg).

117
In newspapers, magazines, and other reading material for the general public, a numeral may be shown in numeric form followed by the unit fully spelled out (e.g., "16 cubic metres"). However, this is not preferred practice in technical or scientific text. If the symbol may not be known to the reader, the name of the unit should be included in parentheses after the symbol:

in a newspaper: 101 kilopascals
in a science text: 101 kPa
in a text for young students: 101 kPa (kilopascals)

118
Sometimes a unit symbol is shown without a numeral or a numeral is shown without a unit symbol, for instance:

- where several measurements are listed and may be inferred to be of the same unit of measurement:
  at the head of a column of data in a table (see 048)
  on the axis of a graph (see 047)
  where all dimensions are in the same units (a 20 by 30 by 40 cm carton)
- where unit symbols are defined or discussed:
  The symbol for gigajoule is GJ.
  Note the difference between Mg and mg and between Mg and Gm.

Appendix D

Some Poisonous Plants

See subsection 9.4, "The Safe Use of Plants".

Legend
The following list includes some poisonous plants that can cause:

- stomach and intestinal irritation (1);
- poisoning of the system (2);
- mouth and throat-lining irritation (3);
- skin irritation (4).

House Plants
caladium (1, 3)
castor bean (1, 2)
dieffenbachia (1, 3)
elephant's ear (1, 3)
lantana (2)
mistletoe (1, 2)
philodendron (1, 3)
poinsettia (4)

A number of other poisonous plants, which are not native to Canada, are also grown indoors.

Vegetable Garden Plants
potato – new shoots (2)
rhubarb – leaf blade (2)

Flower Garden Plants
autumn crocus, meadow saffron (2)
Christmas rose (1, 4)
daffodil (1)
foxglove – leaves and seeds (2)
golden chair (2)
hyacinth (1)
iris, blue flag (1)
larkspur, delphinium (2)
lily of the valley (2)
monkshood (2)
morning glory (2)
narcissus (1)
snowdrop (1)
sweet pea – in large amounts (2)

Ornamental Plants
daphne (1)
mountain laurel (2)
rhododendron (2)
wisteria (1)

Field Plants
buttercup (1)
death camas (2)
false hellebore (2)
poison hemlock (2)
poison ivy (4)
pokeweed, inkberry (1, 2)
snow-on-the-mountain (4)
thorn apple, jimson weed (2)

Trees and Shrubs
black locust (1, 2)
box (1, 2)
cherry – twigs, leaves, and bark (2)
elderberry, black elder (2)
horse chestnut (1, 2)
privet (1)

Marsh Plants
cowslip, marsh marigold (1)
skunk cabbage (1, 3)
water hemlock, cowbane (2)

Forest Plants
baneberry (1, 2)
bloodroot (1, 2)
deadly amanita (2)
fly agaric mushroom (2)
jack-in-the-pulpit (1, 3)
May apple (1)
moonseed (2)
poison ivy (4)
poison oak (4)

Appendix E

Some OAIP Instrument Types and Learning Domains

The following lists will serve as a guide to those designing items for the OAIP pool for Intermediate Division science.

Instrument Types

Selected-response instruments
- alternate response
- multiple choice
- matching exercise

Created-response instruments
- short answer
- completion
- restricted-response essay
- extended-response essay
- numerical problem

Laboratory test instruments
- laboratory skill
- laboratory experiment

Observation instruments
- checklist
- rating scale

Learning Domains (Modified Klopfer)

A. *Knowledge and Comprehension*
A.1 Knowledge of specific facts
A.2 Knowledge of scientific terminology
A.3 Knowledge of concepts of science
A.4 Knowledge of conventions
A.5 Knowledge of trends and sequences
A.6 Knowledge of classifications, categories, and criteria
A.7 Knowledge of scientific techniques and procedures
A.8 Knowledge of scientific principles and laws
A.9 Knowledge of theories or major conceptual schemes
A.10 Identification of knowledge in a new context
A.11 Transition of knowledge from one symbolic form to another

B. *Observing and Measuring*
B.1 Observations of objects and phenomena
B.2 Description of observations, using appropriate language
B.3 Measurement of objects and changes
B.4 Selection of appropriate measuring instruments
B.5 Estimation of measurements and recognition of limits of accuracy

C. *Seeing a Problem and Seeing Ways to Solve It*
C.1 Recognition of a problem
C.2 Formulation of a working hypothesis
C.3 Selection of suitable tests of a hypothesis
C.4 Design of appropriate procedures for performing experiments

D. *Interpreting Data and Formulating Generalizations*
D.1 Processing of experimental data
D.2 Presentation of data in the form of functional relationships
D.3 Interpretation of experimental data and observations
D.4 Extrapolation and interpolation
D.5 Evaluation of a hypothesis under test in light of data obtained
D.6 Formulation of generalizations warranted by relationships found

E. *Building, Testing, and Revising Theoretical Models*
E.1 Recognition of the need for a theoretical model
E.2 Formulation of a theoretical model to accommodate knowledge
E.3 Specification of relationships satisfied by a model
E.4 Deduction of new hypotheses from a theoretical model
E.5 Interpretation and evaluation of tests of a model
E.6 Formulation of a revised, refined, or extended model

F. *Applications of Mathematics and Science*
F.1 The application of science in the same science discipline
F.2 The application of science in another science discipline
F.3 Application to problems outside science and technology
F.4 Mathematical problem solving without the use of formulas
F.5 The use of a single formula in problem solving
F.6 The use of two or more formulas together in a problem

G. *Manual Skills*
G.1 Development of skills in using common laboratory equipment
G.2 Performance of common laboratory techniques with care and safety
G.3 Performance of a full-fledged laboratory experiment
G.4 Drawing and/or labelling diagrams

H. *Attitudes and Interests*
H.1 Showing of favourable attitudes towards science and scientists
H.2 Acceptance of scientific inquiry as a way of thought
H.3 Adoption of scientific attitudes
H.4 Enjoyment of science experiences
H.5 Development of interests in science and science-related activities
H.6 Development of interest in inquiring about a career in science

I. *Science Orientation*
I.1 Understanding of interrelationships between scientific statements
I.2 Recognition of philosophical influence and limits of science
I.3 Recognition of the historical perspective of science
I.4 Realization of relationships among science, technology, and economics
I.5 Awareness of social and moral issues related to science

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